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FEASIBILITY FOR RESEARCH APPLICATION OF VISUAL ATTACHMENTS FOR DYNAMIC FLIGHT SIMULATORS
REPORT NO. 2: REQUIREMENTS AND STATE-OF-THE-ART EVALUATION

John A. Whittenburg
James E. Wise

HSR-RR-62/10-Mk-X

February 1963

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Project No. 421-12R

Prepared for
FEDERAL AVIATION AGENCY
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

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ARLINGTON 1, VIRGINIA

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"This report has been prepared by Human Sciences Research, Inc., for the Systems Research and Development Service, Federal Aviation Agency, under Contract No. FAA/BRD-401, Project No. 421-12R. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA."

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John A. Whittenburg and James E. Wise, February 1963
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ABSTRACT

This report identifies human factors research requirements for visual attachments to dynamic flight simulators, evaluates the state-of-the-art in visual simulation techniques for meeting these requirements, and discusses, within the context of a research and development cycle, alternative study settings (e.g., laboratory, simulation, and field) for investigating different types of human factors problems associated with visual cues and pilot performance.

Current research problems dealing with visual cues and pilot performance during terminal flight and ground phases are grouped according to the nature of the task involved and types of variables related to the performance of these tasks. Three categories were used for grouping current problems:

1. Detection/Identification Requirements: Problems in this group are concerned with the photometric/colorimetric properties of airport and aircraft lights and markings as the independent variables. These studies contribute to the design and development of marking and lighting components and systems.

2. Guidance Requirements: Problems in this area deal with the alignment, spacing, and configurational properties of airport lights and markings as the independent variables. These studies contribute to the design and development of airport lighting and marking patterns.

3. Pilot Related Variables: Problems in this area involve studies on the effects of such variables as pilot fatigue, work load, and operating environment on pilot performance during terminal flight and ground phases. These studies contribute to the development of pilot selection and training programs and to policies regulating pilot procedures and performance standards.

This classification procedure is used as a guide in establishing visual simulation requirements and criteria.

The identified requirements and criteria are used to evaluate six (6) major techniques employed by industry in developing visual attachments to dynamic flight simulators. Within the current state-of-the-art, none of the techniques are evaluated as meeting the visual fidelity requirements necessary to study detection/identification problems. The Synthetic Image Generation technique is feasible with some limitations, for investigating guidance problems. Examples of this technique include the Dalto Scanalog Visual Attachment, the Link Night Landing Display, and the Goodyear Synthetic Image Data Generation system. The Film, Direct Viewing, and Closed Circuit Television Techniques are evaluated as feasible techniques, with some limitations, for studying pilot related problem areas. The particular technique chosen from among these three will depend upon the nature of the problem and degree of importance placed on visual fidelity vs. their respective equipment capabilities. Examples of the Film technique include the Kearfott Celestial/Terrain Viewing System and the Link Mark II Visual System. An example of the Direct Viewing technique is the Contact Flight Trainer, Device 12-L-2. Examples of the Closed Circuit Television technique are the Curtiss-Wright Visulator and the Link Visual System, MK IV and IVA.

Regarding alternative study settings within the context of a R & D cycle, four major considerations are listed as useful in selecting an appropriate study setting. Five types of study settings and major variants for investigating visual problems are identified and described. Finally, recommendations are made with regard to which problems involving visual cues and pilot performances can most effectively and efficiently be investigated in what types of study settings at different stages in the R & D cycle.

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I. Introduction

A. Background and Scope

The rapid growth of U. S. aviation during the past twenty years, coupled with the introduction of new and different types of aircraft in civil and military aviation, has created numerous and diverse demands on the nation's aviation facilities. In 1956 (1) and again in 1961 (9), two long range studies were conducted to determine the nature and magnitude of present and future demands upon the Federal Government for aviation facilities and to establish a requirement for a program of research and development to meet the problems created by these demands. The problems and problem areas identified during the conduct of these two studies formed the basic guidelines for much of the recent past, present, and planned research and development activities of the Systems Research and Development Service (formerly the Bureau of Research and Development) of the Federal Aviation Agency.

Many of the research and development problems identified during these two studies have direct implications for human factors studies on the design and testing of visual aids and for studying factors (e.g., pilot work load) which effect the pilot's proficiency in utilizing available visual aids and cockpit displays. These identified problems differ in their complexity, nature, and in terms of available state-of-the-art information and knowledge that can be used to help solve these problems. As a consequence, both basic and applied human factors research studies have been conducted and are still required to provide useful information on which to base effective decisions regarding external visual aids, cockpit displays, and operational policies pertaining to pilot performance requirements. However, the rapid growth of U. S. aviation and its demands on aviation facilities and pilot performance requirements do not permit extended periods of time for conducting these basic and applied research studies. Timely information contributing to solutions of these problems is needed to keep pace with the changing and growing demands in the field of U. S. aviation and its support facilities.

Early recognition of this problem has resulted in the initiation of an overall airport marking and lighting system concept for an integrated research program. The ultimate objective of this research program involves the most effective and efficient combination of study setting techniques at a reasonable capital outlay to accelerate research and control in the areas of visual aids, cockpit displays, and significant pilot problem areas.

Within the context of this overall research program, the primary emphasis and scope of this study is focused on the question of the potential research usefulness of "real world" visual attachments to dynamic flight simulators.[1] In addition, attention is given in this study to alternative study settings which may offer productive research environments for investigating problems and aspects of problems not appropriate for "real world" visual simulators.

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1. A "real world" visual attachment is defined in this study as one which provides the observer with a field of view similar to what he perceives in the real world. It consists of simulating the appearance of familiar objects, of lights, of terrain and ground contour in the apparent sizes and spatial relationships seen by the pilot if he were actually flying. Appropriate perspective changes in the field of view are made as a function of control responses. Other forms of visual simulation are described in Section VI of this report.

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B. Purposes

Within the above-mentioned scope there are three study purposes:

1. To assemble, classify, and delineate already identified problem areas, (such as the problem of developing design criteria for optimal lighting at secondary airports) which involve the pilot's effective utilization of visual sources of information in performing flight tasks.

2. To select those research problems that can be productively investigated within the context of "real world" visual attachments to dynamic flight simulators. Selection of these research problems is based on both the nature and requirements of the problems and the technological state-of-the-art industry to design and develop visual attachments.

3. To identify and describe alternative research study settings and visual simulation techniques within the context of an R & D cycle which offer productive approaches for investigating problems or aspects of problems not suitable for investigation by "real world" visual attachments to dynamic flight simulators.

C. Sources of Information

Sources of information used in this study are grouped below according to the purpose for which the information was obtained. References are listed in the attached bibliography. The above-mentioned three purposes provide a convenient method for classifying the major sources of information.

1. Identification and Classification of Problem Areas

a. Reports covering long range studies on the nature and magnitude of the demands of U. S. aviation on airport area facilities.

b. Conferences with FAA personnel.

c. Documents prepared by research and development divisions and branches within FAA describing ongoing and planned research studies.

d. Reports which list problem areas identified through interviews with operational personnel (e.g., pilots), personnel in agencies which perform functions directly associated with airport facilities (e.g., National Bureau of Standards), and problems identified as a consequence of analytic and operational studies.

2. Visual Attachment Requirements and Evaluation of Techniques

a. Research reports which discuss problems and requirements for dynamic visual simulators.

b. Trip reports and written materials which describe visual attachment techniques.[1]

c. Books and research reports which describe sensory and perceptual phenomena, and techniques used to study problems in the area of vision.

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1. Industries visited as well as descriptions of their systems and techniques are described in the following reference: Wise, J. E., & Whittenburg, J. A. Feasibility for research application of visual attachments for dynamic flight simulators. Report No. 1: State-of-the-art survey of the visual simulation industry. Arlington, Va.: Human Sciences Research, Inc., July 1962. (HSR-RR-62/7-Mk-X, Contract No. FAA/BRD-401, Project No. 421-12R.

3. Research and Development Cycle and Alternative Study Settings

a. Books and articles which describe the functions and composition of the research and development cycle.

b. Reports by and discussions with research personnel regarding techniques and study settings used to investigate different types of problems.

D. Organization of Report

The report is organized into five remaining major sections:

1. Section II summarizes the demands of U. S. aviation on the nation's aviation facilities during the period 1955 to 1975. The purpose of this section is to identify the important variables associated with past, present and projected airport terminal operations.

2. Section III assembles and organizes problem areas associated with airport terminal operations and describes operational conditions for each. The purpose of this section is to identify the problem context and range of conditions to be considered when investigating each of the problems.

3. Section IV identifies and describes the visual fidelity requirements, and the criteria for "real world" visual attachments to dynamic flight simulators. This section establishes the requirements and criteria applicable to each problem area defined in Section III.

4. Section V summarizes the major dynamic simulator techniques used by industry and evaluates the extent to which these techniques meet the respective requirements and criteria for each type of problem area.

This section identifies which problem areas at present can be productively studied within the context of "real world" visual attachments to dynamic flight simulators.

5. Section VI describes the major elements that make up a research and development cycle, discusses various types of study settings appropriate for investigating problems involving visual information inputs, and lists examples of the types of problems investigated or planned for these study settings. The purpose of this section is to describe alternative visual study settings that may be used to study problems not applicable for "real world" visual attachments to dynamic flight simulators.

II. U.S. Aviation Demands on Airport Facilities and Implications for Visual Simulation Requirements

A. Introduction

In developing specifications for a visual attachment to a dynamic flight simulator or, for that matter, developing specifications for any type of visual study setting (e.g., field or laboratory), one of the prerequisites involves a determination of the operational context and conditions to be visually simulated. To satisfy this prerequisite, answers to three questions are required.

1. What is the nature of the operational context to be simulated?
2. What are the variables and conditions to be simulated?
3. What are the tasks required of the subjects, i.e., pilots?

The present and projected activities of U.S. aviation and the nature of the resulting demands placed on the nation's airport and aircraft facilities provide relevant background information for answering the above three questions. General background information is briefly summarized in this section, amplified in Section III of this report, and discussed in Appendix A of this report. Much of the data reported in this section came from two long range studies in the area (1, 9).

B. Summary of Background Information

The information obtained on present and projected demands of U.S. aviation on the nation's airport facilities is organized and summarized with respect to the three questions asked above.

1. The Operational Context

Most of the critical problems regarding air traffic and safety originate during terminal operations in major airport areas. A second major set of problems stem from the demands placed on secondary airports to provide adequate navigational and visual aids for both IFR and VFR flight. Communities with secondary airports cannot afford developments being incorporated into major airports. As a consequence, an objective of several present and planned research studies is to design and develop low cost but functionally adequate equipment systems and components for secondary airports. In summary, the critical operational contexts for investigating human factor problems associated with visual information to pilots during various flight phases is confined to terminal operations (as contrasted with enroute operations) in major and secondary airports.

2. Operational Variables and Conditions

The major classes of variables and conditions reviewed and compared include:

Aircraft Class: Rotary wing vs. fixed wing aircraft
Flight Conditions: IFR vs. VFR
Types of Aviation: Air carrier vs. general aviation
Types of air carrier and general aviation aircraft

A detailed description of these variables and conditions may be found in Part II of Appendix A, and the background information and data concerning these variables and conditions in Part I of Appendix A. The major findings are summarized below for each of these classes of variables and conditions.

a. Aircraft Class. The great majority of terminal operations for the next several years will involve fixed wing aircraft. By 1975, it is projected that fixed wing aircraft will account for approximately 86% and helicopters for the remaining 14%. On the other hand, the rate of growth in terminal operations presents a considerably different picture. Per cent of helicopter terminal operations was 9% in 1960 and projected to increase to 14% by 1975, while terminal operations for fixed wing aircraft are projected to decrease from 91% in 1960 to 86% by 1975. Although, fixed wing aircraft will continue to predominate terminal operations, the anticipated rate of growth in helicopter operations poses some unique human factor problems in the area of visual and navigational aids.

b. IFR vs. VFR. Terminal operations under VFR conditions do and will continue to constitute the major bulk of all terminal operations. In 1960, 90% of all terminal operations occurred under VFR conditions, and projected to be 86% by 1975. However, the increase in IFR terminal operations from 10% in 1960 to 14% in 1975 coupled with the more severe problems involved in operating under IFR will continue to make this a major R & D area. Several of the present and planned research and development efforts are focused on various human factor problems which stem from IFR conditions.

c. General Aviation vs. Air Carrier Aviation. General aviation will continue to be the dominant factor by 1975; 82% as against 18% for air carrier aircraft. Continued rate of growth in terminal operations for general aviation aircraft is projected to occur under both VFR and IFR conditions. With regard to air carrier aviation, no projected increase in VFR operations is anticipated by 1975. The same rate of growth under IFR conditions is projected for air carrier aircraft as for general aviation aircraft.

d. Air Carrier and General Aviation Types of Aircraft. Heavy single-engine type aircraft will account for over 66% of all general aviation aircraft by 1975. The fastest rate of growth is in the light two-engine aircraft. By 1975, the two aircraft types will constitute over 85% of all general aviation aircraft. Large turbojet transport and medium turboprop transport aircraft will account for about 62% of all air carrier aircraft by 1975. The large trubojet transport aircraft is predicted to have the greatest rate of growth in per cent for air carrier aircraft. Supersonic jet transport and V/STOL aircraft (excluding helicopters) represent fairly unique types of aircraft. Although, there may be a few supersonic transports by 1975, it is anticipated that their performance characteristics during terminal operations will be quite similar to present-day large turbojet aircraft. The effect of V/STOL aircraft on terminal operations is difficult to estimate since the concept has resulted in a variety of versions that are being currently explored.

3. Pilot Task Requirements

The major bulk of the material covering pilot task requirements is presented in Section III of this report. However, a proposed concept of terminal operations at major airports has general implications regarding the nature of pilot task requirements. A concept has been proposed which physically and operationally separates VFR and IFR traffic and within each of these two categories further separates aircraft of widely differing performance capabilities. The concept proposes to segregate aircraft according to capability along climb and approach corridors to and from low, intermediate, and upper airways cruise altitudes. The concept envisions an approach control area of 25 miles radius around a controlled airport increasing to 50 miles at high altitude with a local control radius extending to the outer marker, approximately 4 miles. Controller vectoring and terminal VOR would be used to implement the concept. This concept would eliminate the conventional "downwind, base leg, and final approach" pattern.

C. Implications for Visual Study Setting Requirements

The background data and information summarized above has somewhat broad but direct implications for identifying the operational context and conditions to be simulated in visual study settings. Some of the major implications that the above findings do have on guiding development of requirements for visual study settings are as follows.

1. Operational Context

Study setting contexts are and will be primarily confined to visually simulating features normally found in major airport areas and secondary airports. The terminal airport area to be visually simulated may be divided generally into two sizes reflecting the types and numbers of human factor problems requiring investigation.[1] The first area size (Area One) encompasses a horizontal distance ranging from about 5 miles to 25 miles from an airport location and a vertical distance ranging from about 1500 - 2000 feet at 5 miles to approximately 7000 - 8000 feet at 25 miles.[2] The second area size (Area Two) encompasses a horizontal distance from the airport location to a distance of about 5 miles and a vertical distance from 0 feet at the airport to approximately 1500 - 2000 feet at 5 miles. In Area One, such problems as conspicuity of aircraft, airport identification, and

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[1] Although terminal control is projected to extend out to 50 miles at higher altitudes, most of the human factor problems reported in Section III which have "initial approach" and "climb-out" implications can be studied for the most part, within the 5 - 25 mile area discussed next.

[2] These are approximate area dimensions based on available sources of information. Further effort is required to more precisely determine the required area dimensions.

visual guidance requirements in designated CVR flight terminals can be investigated. Area One is primarily concerned with problems associated with major airport areas. In Area Two, such problems as distinguishing taxiway lights from runway lights, compatibility of approach and runway lights, and ramp identification can be investigated. Area Two includes problems associated with both secondary and major airports. The heavy preponderance of problems reported in Section III are suitable for study in the Area Two context. As a consequence, it would appear that major effort be devoted to the development of equipment specifications needed to adequately simulate the visual characteristics within the immediate airport area, i.e., within Area Two dimensions.

2. Aircraft

Although simulating the flight characteristics of fixed wing aircraft should continue to predominate the majority of human factors research studies for the next several years, the anticipated rapid growth in helicopter terminal operations will require increasing attention to the requirement for simulating the flight parameters of helicopter and V/STOL aircraft. Within the general fixed wing aircraft category, both large turbojet and medium turboprop represent the major types of projected air carrier aircraft. The structural and aerodynamic flight properties of these two types of aircraft will continue to be involved in several of the human factors studies concerning visual aids and cockpit displays. Within the general aviation category, both heavy single-engine and light two-engine aircraft are most representative of this category. Studies concerned with general aviation type of aircraft should involve simulation of these two types of aircraft.

3. Flight Conditions

Previously stated projections regarding magnitude of terminal operations indicate that research emphasis should be placed on studying human factors problems dealing with general aviation aircraft under both VFR and IFR conditions and investigating problems involving air carrier aircraft under IFR conditions. Furthermore, the attention to problems associated with IFR conditions should continue to increase concurrent with the projected rate of increase in U. S. aviation demands for terminal operations under IFR flight conditions.

4. Flight Phases

One of the significant factors identified in the background material reviewed is the implications that the proposed concept will have on the tasks required of the pilots. The proposed concept for controlling and processing aircraft in major airport areas will eliminate circling as one of the common flight phases and require extended ranges when executing straight-in approaches and departures from the airports. In addition, the requirement by aircraft to use flight tunnels to transition through a controlled airport area or to land in an uncontrolled airport will pose requirements on pilots to effectively use both pre-established external natural and coded visual cues to ensure a flight track well within the confines of the air "tunnel". Although the proposed concept should increase control and efficient processing of aircraft during terminal operations, it seems that this may be achieved at the cost of placing greater requirements on the pilots. For this reason, some of the research problems identified in Section III deal with the implications of this proposed concept for human factors research.

III. Identification and Classification of Problem Areas

A. Introduction

The identification and classification of problem areas requiring human factors studies on visual aids and cockpit displays involved the accomplishment of three steps:

1. Problem areas were identified through a number of sources; the demands of U. S. aviation on airport area facilities were reviewed; conferences were held with personnel in FAA; documents prepared by research and development divisions and branches in FAA describing on-going and planned research studies were read; reports were reviewed containing a summary of problems noted by operational and research personnel who are intimately familiar with current and projected airport and heliport marking and lighting requirements.

2. A classification procedure was developed which divides the identified problem areas into three classes. These three classes reflect the commonality of the visual and perceptual tasks required of the pilot during terminal flight phases and the nature of the independent variable of interest.

3. The type and range of relevant operational conditions and variables associated with each problem area were identified using background information presented in Appendix A and summarized in Section II above.

B. Identification of Problem Areas

One of the major sources consists of two long range studies covering the nature and magnitude of the demands of U. S. aviation on airport area facilities (1, 9). Another major source consists of conferences held with cognizant FAA personnel for the purpose of identifying and describing both broad and specific problems requiring human factors studies on visual aids and cockpit displays (including windscreen displays). Names of the personnel contacted are listed in the acknowledgment section of this report. A third source consists of planning and progress report type of documents prepared by research and development divisions and branches within FAA (10, 11, 12, 13, 25). A fourth source involved a review of reports which briefly stated and, in some cases, described in some detail problems and problem areas currently being investigated or the requirements that exist for such investigations (26, 34, 35, 36, 41, 42, 51, 52).

A total of 30 problem areas were identified through these sources. See Charts 1, 2, and 3 in this section of the report. Because of the diversity of these sources, the problems identified range from quite specific problems to rather broad problem areas. Although it is believed that the list of 30 problem areas and problems is representative of the types of human factors studies required in the area of visual aids and aircraft displays, there is no assurance that the list is either exhaustive or necessarily reflects the relative criticality of the total population of existing problems and problem areas. The task of rank ordering the problems and problem areas in terms of their relative criticality is an important task since it affects decisions concerning which problem areas have the higher research priorities. However, accomplishment of this is beyond the scope of the present study. The task that is accomplished in this report is the identification of the types of visual study settings that appear to meet most adequately the requirements for studying the 30 identified representative problem areas.

C. Classification of Problem Areas

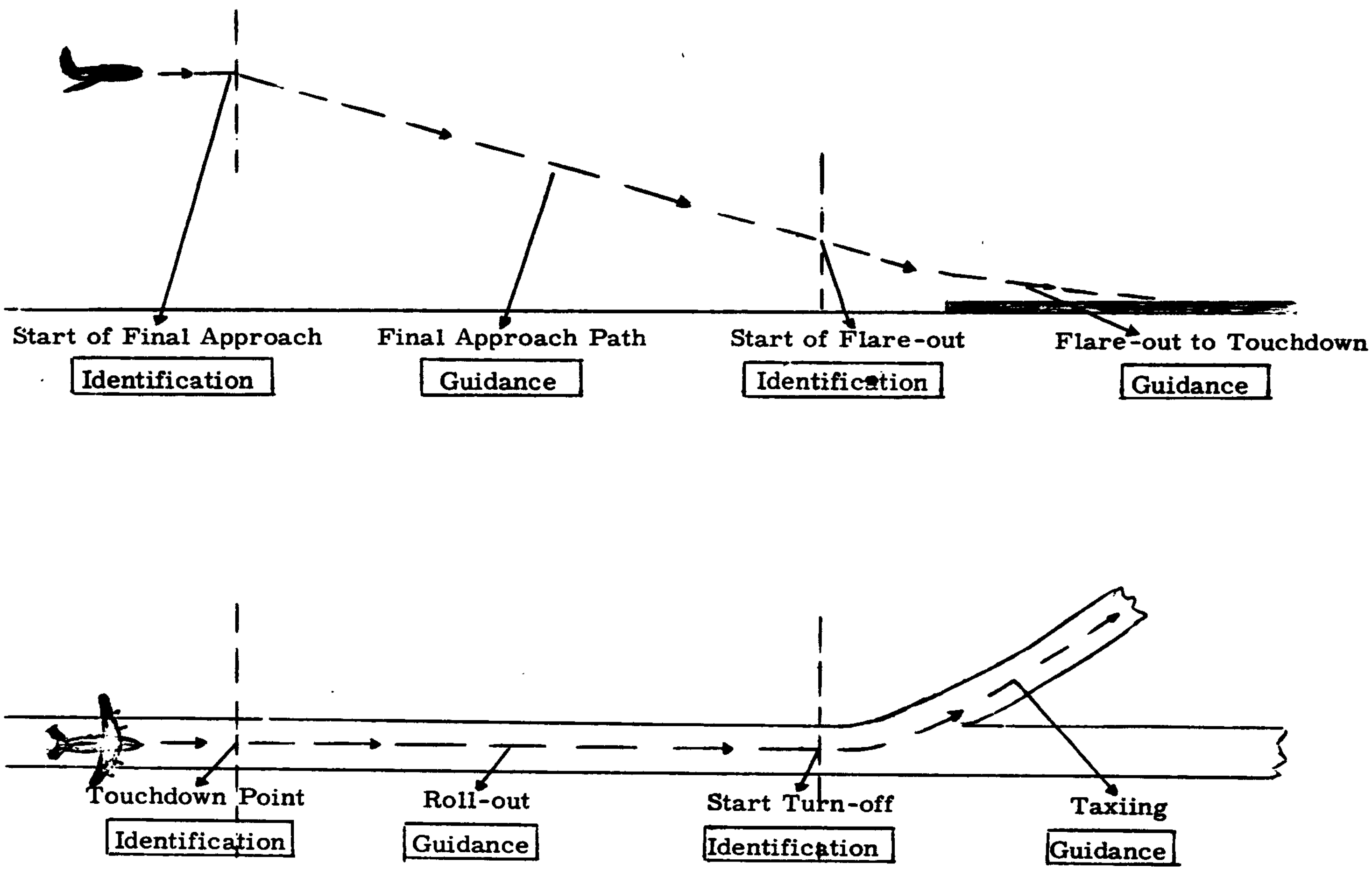
The point of departure for developing the classification procedure is a description of conventional aircraft flight and ground phases and related visual information requirements. Charts A-5 and A-6 in Part II of Appendix A list these typical flight/ground phases for both fixed wing aircraft and helicopters and identify the types of visual information required by the pilot to effectively perform each of these phases. The major references used to obtain this information are listed in the bibliography attached to this report (6, 15, 30, 34, 36, 38, 52).

The typical sequence of flight/ground phases includes initial approach, circling (secondary airports), final approach, flare-out and landing, turn-off and taxiing, and takeoff and climb-out. Inspection of the information contained in the two charts in Appendix A suggests that all flight phases for both fixed wing aircraft and helicopters involve the sequential execution of two qualitatively different tasks by the pilot:

1. Those tasks requiring visually detectable and identifiable object and/or ground cues which enable the pilot to effectively transition from one flight/ground phase to the next phase.
2. Those tasks requiring visual guidance types of information by the pilot in order to effectively progress through a given flight/ground phase.

Figure 1 graphically illustrates this classification of flight and ground phases into two qualitatively different types of tasks. In the case requiring the pilot to detect and identify object/ground cues, the tasks

FIGURE 1: TWO GRAPHIC ILLUSTRATIONS SHOWING THE DELINEATION OF FLIGHT/GROUND PHASES INTO THE TYPE OF VISUAL CUES REQUIRED: IDENTIFICATION OR GUIDANCE CUES



are initiated when the pilot correctly detects and identifies by use of natural and/or coded visual cues the existence of particular spatial and temporal relationships of the aircraft with regard to some external referent(s) (e.g., point or area location on the ground). These tasks are terminated when the decision is made to change the aircraft's spatial and temporal relationship with respect to the external referent, i.e., to change from one phase of flight to another flight phase. The tasks requiring guidance information involve the execution of necessary compensatory control movements by the pilot for the purpose of having the aircraft achieve and maintain a "stable" or steady-state relationship with respect to some external referent or referents. In the first case, the pilot's task is to recognize at some designated or appropriate point along a flight path when to transition from a present phase of flight to the next phase. In the latter case the pilot's task is to attain and maintain a prescribed flight or ground track whether the track is changing in some consistent manner or remains identically the same in terms of the aircraft's attitudinal and translational relationships with the ground.

These two tasks in addition to a third variable may be further classified in terms of the independent variable of interest. With respect to the tasks involving correct and timely detection and identification of object/ground cues, the independent variables of interest stem from questions concerning sensory and perceptual thresholds of the pilot during terminal operations. Such questions as intensity of lights, colors of lights, size and shape of markings, the effects of low visibility on sensory and perceptual thresholds, and even threshold questions concerning natural cues belong to this cateogry. The independent variables include photometric, colorimetric, ambient (atmospheric), and spatial (object size and shape) properties of man-made or natural sources of visual cues. With respect to the tasks involving guidance information, the independent variables of interest stem from questions regarding the placement of lights and objects to provide sensitive indicators of deviations from a desired flight or ground track. With respect to guidance problems, the visual sources are well above sensory and perceptual thresholds, and the questions deal with the spacing, alignment, and configuration of both man-made and natural cues which are used to provide necessary guidance information. The third variable which is a different independent variable is the pilot himself. In the first two instances, different parameters of hardware and the external world constitute the independent variables, i.e., those features of hardware or natural objects which are altered by design or by selection. In this case, the pilot is the independent variable of interest. Some of the critical problem areas reported deal with the basic question of pilot reliability and the effects of various factors, other than visual aids, on the effectiveness and efficiency with which the pilot can utilize visual aids in performing the terminal flight and ground phases. Any significant decrease in the sensory, perceptual, decision making, or control response capabilities of the pilot adversely effects the accomplishment of the required terminal operations. Such factors as aging, fatigue, task load, or boredom (inattentiveness) may bring about severe reduction in overall performance effectiveness. Considering the pilot as an independent variable, those aspects which can be manipulated include pilot screening, training, required cockpit procedures and tasks, maximum length of flights, and so forth.

D. Operational Conditions Associated with Problem Areas

The third step involves the identification of the operational conditions and variables associated with each of the problem areas. The material presented in Section II and Appendix A produced four categories representing the major operational conditions and variables. This section discussed the fifth category, i.e., flight and ground phases. These categories include:

1. Fixed Wing Aircraft vs. Rotary Wing Aircraft
2. IFR vs. VFR Flight Conditions
3. General Aviation vs. Air Carrier Aircraft
4. Types of General Aviation and Air Carrier Aircraft
5. Flight and Ground Phases

Using these categories as guides, specific conditions and variables are identified and related to each problem area. The implementation of this step is contained under the heading "Delineation of Problem Area Conditions" in Charts 1, 2, and 3. The problems listed in Charts 1 - 3 present all available information on problems and problem areas associated with pilot performance during airport terminal operations. Many of these listed problems are not suitable for investigation by use of closed loop "real world" visual attachments. Section V of this report identifies which of these 30 problems are suitable for study with "real world" visual attachments, and Section VI identifies alternative study settings suitable for investigating those problems not appropriate for "real world" visual attachments.

CHART 1: LISTING AND DELINEATING PROBLEM AREAS INVOLVING DETECTION/IDENTIFICATION REQUIREMENTS

Reported Problem Areas	Delineation of Problem Area Conditions
1. Conspicuity of Aircraft	Major airport areas, general aviation (heavy single-engine and light twin-engine aircraft), marginal day and night VFR, terminal operations, and transient flights within radius of controlled airport areas.
2. Detection and Identification of Tall Obstructions (e.g., TV Towers)	Major airport areas, day under marginal VFR conditions and night VFR, initial approach, and climb-out.
3. Airport Identification	Major airport areas (airport beacons and airport color and brightness contrast with surround), initial approach.
4. Distinguishing Taxiway Lights from Runway Lights	Major airports, night VFR, initial approach.
5. Duty Runway Identification	Major airports (e.g., parallel runways), day and night VFR, especially during initial approach.
6. Compatibility of Approach and Runway Lights	Major and secondary airports (light intensity and spacing), night VFR and IFR, final approach, flare-out and touchdown.
7. Legibility of Runway Distance Markers	Major and secondary airports, air carrier (medium and large transports), night VFR and IFR, roll-out and takeoff (including high speed turn-offs).
8. Distinguishing Runway Exits from Runway Edge Lights	Major and secondary airports, air carrier (medium and large transports), night VFR and IFR, roll-out, and turn-off.
9. Compatibility of Approach and Runway Light Intensity with Ambient Conditions	Major and secondary airports, night VFR and day and night IFR, initial approach, final approach, flare-out, and touchdown.

CHART 1 (continued)

Reported Problem Areas	Delineation of Problem Area Conditions
10. Conspicuity of Airport Surface Vehicles	Major airports, day IFR, and night VFR and IFR, taxiing to and from ramps and service areas.
11. Ramp Identification	Major airports, day and night VFR and IFR, taxiing to ramps.
12. Taxiway Route	Major airports, day and night VFR and IFR, taxiing to and from ramps.
13. Heliport Identification	Heliports located in major airports, air carrier (helicopters), day and night VFR and IFR, initial approach.
14. Heliport Design Criteria for S/VTOL Aircraft (Identification Cues Required when Transitioning from One Flight Phase to Another) (See also related guidance problem area)	Heliports and helipads, air carrier (helicopters), day and night VFR and IFR, initial approach, circling, final approach, hover, touchdown.

CHART 2: LISTING AND DELINEATING PROBLEM AREAS INVOLVING GUIDANCE REQUIREMENTS

Reported Problem Areas	Delineation of Problem Area Conditions
1. Natural and coded visual cues to provide directional guidance within controlled airport areas (i.e., in designated CVR flight tunnels and corridors).	Major airport areas, general aviation type of aircraft and air carrier helicopters, marginal day and night VFR, terminal operations and transient flights within radius of controlled airport areas.
2. Factors effecting configurational (guidance) integrity of airport lighting systems.	Major and secondary airports, night VFR and IFR, final approach, flare-out, touchdown, roll-out, turn-off, taxiing, and takeoff.
3. Low cost approach lighting for secondary airports.	Secondary airports, day IFR and night VFR and IFR, final approach.
4. Patterning of lights/markers to provide directional and distance guidance during circling.	Secondary airports and heliports, day and night VFR, general aviation and air carrier aircraft and helicopters, circling.
5. Height guidance during final approach and flare-out.	Major and secondary airports, day marginal VFR and IFR, and night VFR and IFR, final approach, and flare-out.
6. Comparison of proposed approach and runway marking and lighting systems (e.g., Netherlands approach and transition zone lighting system).	Major airports, air carrier aircraft (medium and large transports), day and night VFR and IFR, initial approach, flare-out, touchdown, roll-out and takeoff.
7. Design criteria for all weather optimal runway lighting systems at major airports (guidance properties of runway lights).	Major airports, all aircraft types, all ambient conditions, final approach, flare-out, touchdown, roll-out, and takeoff.

CHART 2 (continued)

Reported Problem Areas	Delineation of Problem Area Conditions
8. Design criteria for optimal lighting system at secondary airports (guidance properties of lighting systems).	Secondary airports, light general aviation aircraft and medium transport air carrier aircraft, night IFR and VFR, final approach, flare-out, touchdown, roll-out, turn-off, taxiing, and takeoff.
9. Design criteria for all weather lighting system at heliports (guidance properties of lighting systems).	Heliports at major airports and helipads, helicopters, day and night VFR and IFR, all flight phases except initial approach.
10. Optimal allocation of terminal flight tasks to automatic and manual control system (reliability and accuracy of human vs. automatic control systems).	Major airport areas, air carrier aircraft, night and day VFR and IFR, and all terminal operations.
11. Development of windscreens designed for guidance when transitioning from IFR to VFR.	Major and secondary airports, day and night IFR, final approach, flare-out, touchdown, and roll-out.
12. Development of cockpit display to provide visual guidance compatibility when transitioning from automatic control to manual control under contact flight conditions.	Major and secondary airports, day and night IFR, final approach, flare-out, touchdown, and roll-out.

CHART 3: LISTING AND DELINEATING PROBLEM AREAS INVOLVING PILOT VARIABLES

Reported Problem Areas	Delineation of Problem Area Conditions
1. Effects of pilot aging on contact flight performance during terminal operations. (Selection Procedure)	Major airport areas, air carrier aircraft, night and day VFR and IFR, and all terminal operations.
2. Effects of pilot fatigue on perceptual and motor flight performance during terminal operations. (Selection/ Experimental Manipulation)	Major airport areas, air carrier aircraft, night and day VFR and IFR, and all terminal operations.
3. Effects of pilot task load on contact flight performance during terminal operations. (Experimental Manipulation)	Major airport areas, air carrier aircraft, night and day VFR and IFR, and all terminal operations.
4. Development of manual pilot flight profiles as base standards for evaluating automatic control systems during terminal operations. (Training Standard/ Selection Procedure)	Major airport areas, air carrier aircraft, night and day VFR, and all terminal operations.

IV. Visual Attachment Requirements and Criteria

A. General Comments on Research vs. Training Simulators

The history of dynamic visual flight simulators has been almost exclusively concerned with requirement specifications, design, development, evaluation, and utilization of flight simulators for training purposes.[1] Several excellent reports have been written on various aspects of dynamic simulators for training. A few of these reports are referenced in the attached bibliography (3, 24, 30, 38, 40). To provide a common frame of reference, a few general comments will serve to compare research vs. training simulator considerations and requirements.

1. The great majority of the dynamic flight simulators built for training are normally designed around one and sometimes two operational missions. Furthermore, the flight characteristics of a simulator are designed to match as closely as possible the dynamic characteristics of a special class or type of aircraft for which the training is intended. The savings in training cost and the increase in safety have generally warranted the extensive use of simulators for training purposes. On the other hand, in order for research simulators to "pay-their-way," they must be quite flexible in terms of the number and variety of problems they can investigate. Emphasis is placed on a general purpose aircraft simulator with a visual attachment capable of simulating perceived changes in real world picture or cockpit instrumentation that stem from flight characteristics of a number of aircraft types. In practice one type is considered as representative of a class and is used as the research vehicle.

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1. In this discussion the type of training simulators referred to are the continuous feedback or compensatory type of simulators and not "procedural" trainers.

2. The major a priori criterion of "fidelity" for a training simulator is the extent to which it achieves "phenomenological equivalence" with the actual operational situation or "perceptual fidelity" when referring primarily to the visual simulation aspects. The objective is to maximize transfer of pilot training from the simulator to performance in the actual aircraft. The primary criterion source for determining the extent of fidelity of training simulators is the pilot, i.e., the human operator, and the ultimate check on its fidelity is the extent of transfer of training attained. With regard to research simulators, the major criterion source is a function of the nature of the problem being studied and the purpose for which the problem is being investigated. The criterion source may be measurable physical properties of the "real world," i.e., utilizing the criterion of physical fidelity, or the fact that the scene viewed is perceived as a sufficiently good analog of the real world. The latter is used when studying pilot related problems. As a further note on this topic, the concept of the "real world" possesses at least three meanings, i.e., physical, perceptual, and retinal (49). The choice of a particular meaning of "real world" is based on which of the three is selected as the criterion for evaluation of the simulation. This is equally true in evaluating visual attachments to a dynamic simulator. An attachment may consist of a physical analog or abstraction of the external world, a combination which contains both physically equivalent properties and perceptually judged equivalent properties, or a display designed to achieve complete perceptual fidelity.

3. Most dynamic flight simulators for training depend on instructors for observing and evaluating the performance of the trainee. However, where measurement equipment is provided, objective measurement of errors, time scores, and accuracy scores are used to supplement the judgments

and ratings of the instructors. Also, in training simulators broader tolerances are established for the operation and reliability of the equipment and requirements for alignment and calibration. On the other hand, dynamic simulators for research purposes normally require the capability for obtaining either or both diagnostic measures and integrated measures. Diagnostic measures generally involve detailed records of control responses, display changes, and flight tracks over time. Integrated measures normally result in a single number which reflects an overall integration of deviation errors in track flight, time to perform a task, etc. In addition, considerably greater emphasis is placed on attaining fine equipment tolerances and high reliability, possessing automatic or semi-automatic alignment and calibration test equipment, and following prepared standardized procedures for checkout and preventive maintenance. The introduction of constant or variable errors introduced by simulator or research equipment may well conceal real differences or mislead the experimenter into assuming the existence of real differences among the treatments when, in fact, a constant equipment bias may be accounting for the difference (2, 16).

Many of the major points covered above are summarized in Chart 4.

B. Identification and Description of Requirements and Criteria

Requirements for visual attachments may be conveniently grouped under two major criterion sources: physical fidelity and perceptual fidelity.

1. Physical Fidelity: Physical fidelity is the capability of simulating properties of the external world. The simulated properties are expressable in the same physical terms as those used to describe the external world. For example, simulation of a pattern of lights on a runway must be expressable

CHART 4: A SUMMARY OF FACTORS COMPARING TRAINING VS. RESEARCH CONSIDERATIONS

Aspects of Simulation	Training Considerations	Research Considerations
Attitudinal and Translational Capabilities of Visual Attachments	Attitudinal and translational ranges and values designed into a visual attachment are matched to the aerodynamic properties of a specific aircraft.	Attitudinal and translational ranges and values designed into visual attachments are capable of effective operation with a variety of flight simulators possessing different flight equations and structural characteristics.
Pilot Task	To improve performance to an acceptable standard. Instructors monitor with the objective of correcting errors.	To determine functional relationship between values of independent variables and measures of performance. A representative sample of pilots needed to allow for individual differences. Objective is to obtain information which bears on design criteria, selection of proposed visual aids or displays, and operational policies or pilot procedures.
Fidelity of Simulation	The visual attachment should meet the criterion of perceptual fidelity.	Depending on class of independent variable to be studied, perceptual fidelity may be adequate, mixed physical and perceptual fidelity may be required, or complete physical fidelity may be needed.
Performance Measurement	Oriented towards one trainee at a time. Generally subjective. Performance may or may not be recorded. Accuracy desirable but often not mandatory.	Subjective measures often made but objective measures over time and pilot population are often required to provide the information in a form needed for operational decisions.
Data Analysis	In individual training, not usual to analyze data statistically. Rather trainee's mistakes are pointed out and daily records kept to record improvements in performance.	Measures of variability and trends are very important. Statistical tests for significance are normally required.

in terms of the same physical scale (linear separation and alignment) as used to physically describe this property of spatial configuration in the real world. The empirical or mathematical relationship between the physical real world properties and their visual simulation may be expressable in approximate or exact form and may consist of all or some of the dimensions of a physical real world variable. For example, it may be possible to simulate only one type of fog with a characteristic density and distribution pattern. Furthermore, the relationship may not be a point by point matching throughout the range required. The extent to which a precise and accurate relationship is simulated provides an index of the degree of physical fidelity attained. The essential factor is that the values of real world characteristics and physical simulation must be determinable and expressable in the same terms and on the same physical scale.

There are four general properties or characteristics of physical phenomena which are of interest: (1) photometric and colorimetric variables, (2) ambient variables, (3) spatial variables, and (4) dynamic variables.

a. Photometric/Colorimetric Variables: Luminous sources, light-transmitting objects, and light-reflecting surfaces provide photometrically and colorimetrically measurable properties of light in the physical real world. These measurable properties of light vary in terms such as intensity, wavelength, energy, areal density, source, flux, and luminance. Simulation of these properties is normally associated with either the development of design criteria for marking and lighting systems and components or testing of the functional effectiveness of the photometric/colorimetric properties of proposed lighting and marking systems and components.

b. Ambient Variables: Quantitative descriptions of the physical composition of elements (i.e., fog, rain, snow, dust, smog, smoke) that occur in the atmospheric medium and the differential transmissivity characteristics of these elements are needed as the basis for visually simulating these properties. The primary concern with ambient variables is the effect that these variables have on the pilot's ability to detect, recognize, and identify correctly and quickly the required natural or coded visual cues during terminal operations.

c. Spatial Variables: Geometric and mathematical descriptions of the perspective of surfaces, contours, and objects provide the appropriate measures for linking the spatial properties of the physical world with the simulation of these spatial properties. These properties of the world itself must be related to the position in space of the viewer. The physical world and (static) simulation of its spatial properties are considered here.

d. Dynamic Variables: Adequate simulation of the photometric/colorimetric intensity variations and dynamic transformations that occur in the perspective of surfaces, contours, and objects with simultaneous changes in the aircraft's attitude and translational relationships are required to achieve dynamic physical fidelity.

2. Perceptual Fidelity: The important requirement for meeting the criterion of perceptual fidelity is the capability of reproducing the phenomenologically descriptive characteristics of the "perceived" real world. If apparent conflicts exist between perceptual and physical fidelity when both are being simulated in a visual attachment, the decision to alter one or the other of the simulated properties so as to eliminate the apparent conflict depends, as pointed out earlier, on the purpose of the study and selection of the appropriate criterion source, i.e., the perceptual or the physical world. The reporting of such conflicts is not necessarily either illogical

or improbable since the attempt to simulate physical properties of real world variables necessarily requires scaling the variables to "fit" the much smaller and normally two-dimensional field of view presentation in a visual attachment. Conflicts of this nature have been noted.[1] Perception of the real world is a joint function of the physiological make-up of the human visual mechanisms plus connecting neural properties and the expectancies developed from prior experience. As a consequence, the "perceived" real world differs among individuals to the extent that there are differences in their physiological make-up, (e.g., visual acuity and color discrimination capabilities) and differences in their experiences, hence differences in their expectations. For this reason, the criterion source for judging the degree of perceptual fidelity achieved in a dynamic flight simulator is based on using a population of individuals whose visual capabilities are similar, and whose experiences are fairly comparable in the area which the simulator is designed to explore.

The criterion of perceptual fidelity is also subdivided into four major classes of variables. These classes of variables are analogous to those used to delineate the physical fidelity domain, but the terms used here reflect the subjective nature of the criterion.

a. Brightness and Color Contrast: This involves the simulation of perceived brightness and color differentials that exist among elements that make up the field of view and vary as a function of such conditions as level of illumination (day or night simulation), distance (aerial perspective), source (incident or reflected light), and nature of the source (surfaces, contours, objects). Knowledge of the psycholophysical relationships that exist between the physical and perceived real world variables, generally

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1. Personal communication with Dr. W. G. Matheny, Life Sciences, Inc., Fort Worth, Texas.

acceptable phenomenological descriptions of visual cues pertaining to brightness and color in a dynamic three-dimensional field of view, and personal experiences are normally used as guidelines in attempting to reproduce perceptually equivalent cues in a visual attachment.

b. Atmospheric Representation: This involves the simulation of the perceptual equivalent(s) of such common atmospheric phenomena as fog, clouds, haze and rain. The major two considerations are that the atmospheric representations "look realistic" and produce perceptually equivalent effects with regard to the simulated elements in the field of view, e.g., the production of glare effects. The extent to which the scope of the (effective) visual field is reduced by such factors for different ranges from the light source(s), and resultant tendencies to lose control of the aircraft while attempting to interpret attenuated visual cues become very important criteria of a more global nature.

c. Object/Contour Representation: This involves the simulation of a three-dimensional field of view in which objects vary in terms of their apparent size, shape, and shading as a function of simulated distance and perspective. The application of such phenomenological principles as linear perspective, interposition of objects, differential texture gradients of surface elements, and knowledge of the visual mechanisms in terms of accommodation, convergence, and stereoscopic vision serve as guidelines in attaining perceptual fidelity with regard to a three-dimensional representation of surfaces, contours, and objects.

d. Apparent Motion Perspective: This involves the simulation of apparent motion in response to pilot control actions. The application of such principles and observations as monocular movement parallax, apparent expansion and differential rates of expansion of the visual field, and directional and rate of directional movement must be represented to achieve realistic motion perspective.

C. Equipment Requirements

In addition to satisfying criteria of visual fidelity, simulators or their visual attachments must meet certain equipment requirements. These requirements are delineated into three categories: (1) management, (2) operation and maintenance, and (3) research.

1. Management Criteria

a. Procurement Cost: Procurement cost is composed of both money and time criteria. Factors effecting both money and time include development funding, field evaluation funding, and direct hardware costs. Generally speaking, the more sophisticated the technique used in providing visual simulation, the higher the procurement costs. Also the research and development stage of a technique contributes directly to the time required and to the probability of a visual attachment adequately satisfying the system specifications.

b. Growth Potential: Growth potential could be labelled as future costs. Growth potential pertains to the capability of a visual attachment to absorb modifications within minimum time and funding requirements to enable the investigation of new and diverse research problems.

c. Packageability: Packageability pertains to the capability of a technique to enable "high density" packaging of components, units, and subsystems and thus minimize operating and storage space requirements.

2. Equipment Operation and Maintenance Criteria

a. Compatibility: Equipment compatibility refers to the capability of a visual attachment to be linked to a dynamic flight simulator in a minimum of time and without the requirement for extra conversion units.

b. Durability: Durability refers to the capability of a technique to withstand the possible detrimental effects of such factors as handling, moisture, heat, usage, power variations, vibrations, and other externally or internally derived conditions normally associated with the equipment's operation and maintenance.

c. Maintainability: Maintainability includes such pre-operational and preventive maintenance capabilities as automatic and semi-automatic calibration and alignment features, checkout equipment and standardized checkout procedures, ease of adjustibility of components, units, and subsystems, and corrective maintenance capabilities as automatic fault isolation equipment, trouble-shooting aids, and ease of replacing malfunctioning components, units, and subsystems.

3. Research Criteria

a. Flexibility: Flexibility refers to the capability of a technique to study a wide range of research problems by being able to simulate the necessary conditions and variables required.

b. Measurability: Measurability refers to the efficiency and accuracy with which performance data can be recorded at cardinal points (e.g., voltage pick-offs and shaft rotation data) and suitably displayed, and to the number of different forms these data can assume, e.g., discrete or continuous in nature and diagnostic or integrated measures.

c. Reliability: Reliability refers to both the consistency with which the total equipment complex performs under various experimental conditions and the accuracy and completeness with which the visually simulated field of view is reproduced when given the same set of control responses under identical simulated flight conditions.

D. Problem Area Requirements and Real World Fidelity Criteria

Section III of this report grouped the 30 reported research problems into one of three classes: detection/identification, guidance, and pilot problems. In Section IV, the distinction between physical and perceptual fidelity was discussed as well as equipment requirements and criteria. The purpose of the remaining paragraphs in Section IV is to specify which physical and perceptual fidelity dimensions are required in visual simulation study settings to appropriately investigate each of these three classes of problems. The end product of relating research problems to fidelity requirements is used in Section V to determine which of 6 major visual simulation techniques may most readily be used to investigate the three classes of problems.

The specific task is to identify those real world fidelity criteria that must be satisfied at some level in the design and operation of visual attachments in order to appropriately investigate different problem areas. A real world visual attachment does simulate by definition and in some manner, all of the major classes of variables identified under B above. These include optical properties of light, physical properties of the atmosphere and the perceptual phenomena that they introduce, geometrically accurate or perceptually realistic surfaces, contours and objects, and dynamic or apparent movement properties. The design task is that of determining which of these real world variables should satisfy physical and perceptual fidelity criteria and requirements for accuracy.

1. Dectection/Identification: Chart 5 shows which of the physical fidelity criteria are required in simulators in which detection/identification problems are to be studied. Chart 6 shows that the single remaining variable requires perceptual fidelity simulation, i.e., apparent motion perspective. To provide a complete set of variables which make up the "real world" within the context of a dynamic flight simulator, the variable of apparent motion perspective was assigned to the perceptual fidelity category. As implied in Section III and illustrated in Figure 2, studies on detection/identification do not require closed loop simulation. However, the capability of providing apparent motion perspective would permit a realistic and continuous transition from one flight phase to another flight phase when the requirement is to study more than one aspect of the detection/identification problem area.

2. Guidance: Chart 5 shows that physical fidelity is required in the areas of spatial and dynamic simulation, and Chart 6 reveals that the remaining classes of variables should be designed in the visual attachment to meet perceptual fidelity. These types of problems are concerned with the spatial arrangement of visual cues and the effectiveness with which these patterns can provide sensitive indications of deviation from a desired flight or ground track.

3. Pilot Variables: Chart 5 shows that no requirement exists for any of the variable classes to satisfy the physical fidelity criterion. The logical criterion source is the pilot since the types of research information required do not relate to any of the physical properties of the real world but to the pilot's perception and performance as a function of such factors as aging, task load, fatigue, etc. Consequently, all variables designed in the visual attachment for investigating factors effecting pilot performance under various conditions must be designed to meet the criterion of perceptual fidelity.

CHART 5: CLASSIFICATION OF PROBLEM AREA REQUIREMENTS IN TERMS OF MEETING PHYSICAL FIDELITY CRITERIA

1 = YES (Required)   0 = NO (Not Required)

	Physical Fidelity Criteria			
Problem Area Requirements	Photometrics/ Colorimetrics	Ambient	Spatial	Dynamic (Unprogrammed)
Detection/Identification[1]	1	1	1	0
Guidance[2]	0	0	1	1
Pilot Variables	0	0	0	0

1. The characteristics or properties of the physical real world which significantly affect detection/identification and the resulting design recommendations that are made are labelled with a numeral 1. Unprogrammed or closed loop simulation is not a pre-requisite as defined by the classification procedure discussed in Section III.

2. The characteristics or properties of the physical real world which significantly affect guidance and the resulting design recommendations that are made are labelled with the numeral 1.. Neither systematic variations in photometric/colorimetric nor ambient variables are involved in the guidance area, since the visual cues must be above visual threshold to adequately study guidance problems independent of problems associated with detection and identification.

CHART 6: CLASSIFICATION OF PROBLEM AREA REQUIREMENTS IN TERMS OF MEETING PERCEPTUAL FIDELITY CRITERIA[1]

1 = YES (Required) 0 = NO (Not Required)

	Perceptual Fidelity Criteria			
Problem Area Requirements	Brightness and Color Contrast	Atmospheric Representation	Object/Contour Representation	Apparent Motion Perspective
Detection/Identification	0	0	0	1
Guidance	1	1	0	0
Pilot Variables[2]	1	1	1	1

1. The categories in Chart 5 which are assigned the numeral 1 (physical fidelity is required) receive a designation of "0" in Chart 6. Likewise, those categories in Chart 5 which are assigned a "0" receive a numeral 1 in Chart 6 (perceptual fidelity required). All variables are represented in a real world visual attachment. The only question is which type of fidelity (physical or perceptual) is required for each class of variables.

2. Studies dealing with pilot problem areas must satisfy perceptual fidelity criteria since the point of reference is the human and not the external physical world.

Performance standards based on normative data provide guidelines for drawing conclusions and making recommendations with regard to existing or proposed operational policies, rules, and procedures effecting pilot selection, assignment, and activities during terminal flight and ground operations.

We are now ready to examine state-of-the-art of simulation techniques to determine which of these techniques may most readily be used to investigate the three classes of problems. It will be noted that we speak of simulation techniques rather than specific visual attachments or systems. The reason is that each technique discussed gives rise to several different types of visual attachments based on diverse engineering approaches.

V. Evaluation of State-of-the-Art Techniques

A. Introduction

The major objective of this study is to determine the research applications of visual attachments to flight simulators or stated differently, "What types of relevant research problems can be effectively studied within the context of current state-of-the-art dynamic (unprogrammed) visual simulation?" Earlier sections of this report identified current problems and the types of requirements visual attachments must satisfy to provide effective research media for investigating different classes of problems. In addition, a separate report contains information on major visual simulation techniques developed by industry and the types of visual attachment systems existing or proposed which employ these techniques and their major variations.[1] This section of the report utilizes this background information as the basis for evaluating current state-of-the-art visual simulation techniques.

B. Description of Major State-of-the-Art Techniques

Six major visual simulation techniques were identified by plant visits, and literature review. These techniques provide the basis for conceptualization, design and test of visual attachment systems. Brief descriptions of these techniques are presented next. A more complete treatment of these techniques and systems is contained in a separate report of this study.

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1. Wise, J. E., & Whittenburg, J. A. Feasibility for research application of visual attachments for dynamic flight simulators. Report No. 1: State-of-the-art of the visual simulation industry. Arlington, Va.: Human Sciences Research, Inc., July 1962. (HSR-RR-62/7-Mk-X, Contract No. FAA/BRD-401).

1. <u>Computation of Pictorial Elements Technique</u>: There are two modes of this technique: projected pictorial elements and nonprojected pictorial elements. In the projected mode, mathematical equations for the geometrical perspective of various objects are computed. Mechanical devices which will produce these geometrical shapes as related to control movements of the aircraft are projected onto a viewing surface. The non-projected mode utilizes flat panels with a high density of display elements. These elements are actuated in such a way as to produce the required visual display. Examples of systems developed/proposed utilizing this technique:

a. University of Illinois Landing Display
b. Rheem Runway Lighting Attachment for Aircraft Simulators

2. <u>Film Technique</u>: Two modes of this technique are available: static or pre-exposed film and dynamic or film exposed during the simulator run. In the static mode film of the real world is taken from an aircraft performing various flight phases. These film are then run through special projectors with lenses of varying widths such as TODD-AO or Cinemascope. Changes in the visual presentation on the screen are programmed to simulator control movements by altering the functioning of variable power and focal length lens and anamorphic attachments. The dynamic mode utilizes film exposed during a "flight" through the model complex. The film can be rapidly processed, transported to a projector, and projected on a screen. Examples of systems developed/proposed utilizing this technique are as follows:

a. Link Mark I Visual System
b. Link Mark II Visual System
c. Bellarama
d. Kearfott Celestial/Terrain Viewing System

3. Direct Viewing (Model) Technique: Direct observation of scale model objects in a model scene through an optical system such as a periscope or viewer is utilized in this technique. The viewer or periscope magnifies the image of the scale model objects and is so designed that the physical dimensions of its entrance pupil allows the observer to go as close to the models as scale position allows. The optical pickup of the periscope is passed over the scale models to simulate relative change in position as a function of control movements. Examples of systems developed/ proposed utilizing this technique are as follows:

a. Contact Flight Trainer, Device 12-L-2

b. Tank Platoon Leader Trainer, Device 17-AR-1

c. American Optical Co., A Periscope for Forward Vision out of High-Speed Aircraft

4. Optical Display Projection Technique: The two types of optically projected displays in this technique are diascopic and epidiascopic projection. In the diascopic systems, light from an external source penetrates a transparency to form an image onto a screen without the aid of lenses. An epidiascopic system uses light which is relected from the surface of an opaque scale model to produce an image by use of lenses. Examples of diascopic type systems are:

a. Contact Landing Trainer, Device 20-L-1

b. Contact Analogue Landing Trainer, Device 20-L-10A

c. Helicopter Flight Simulation Research Tool, Device 2-FH-2

Examples of epidiascopic type systems are:

a. Rheem Modified Visual Flight Attachment for Aircraft Flight Simulation

b. Projected Optical Viewing of Bellarama Display

c. Torpedo and Rocket Attack Trainer

5. Closed Circuit Television Technique: This technique utilizes 3D scale models which are viewed by one or more television cameras. Translational effects are produced by moving either the model or television camera with respect to each other. The camera views the scale models through a special lens system and converts the scene into video signals. These signals are then fed into either a standard television monitor mounted in the windshield of the flight simulator or into a kinescope projector. The projector then projects the scene onto a screen in front of the flight simulator. The camera or model complex, whichever is mechanized, is related to flight simulator control movement. Examples of systems developed utilizing this technique are as follows:

a. Dalto MK III

b. Curtiss-Wright Visulator

c. Link Visual System, MK IV and IVA

6. Synthetic Image Generation Technique: The technique is a composite of film, optics, television, and computer techniques. A transparency or glass plate especially prepared to contain high density data storage is used. Various means are used for rapid extraction and readout of these data.

One variation of this technique selects rays of light reflected from lenticular surfaces after the rays have passed through a specially prepared film record of data. The selected rays are then optically channeled to a projector for projection onto a special screen.

Another variation utilizes flying spot scanners to generate a radial sweep raster and projects this raster onto a glass plate or transparency containing the required data. Photoelectric cells convert the light energy into electrical energy and distribute the signals to appropriate read-out equipment.

Color encoded data laminates are used in still another variation of this technique. Three color transparencies, each containing data, are laminated for increased density storage.

Another variation of this technique utilizes electronic abstraction and computation. Specially prepared ciruit boards generate the electrical signals necessary for presentation, and control movements of the dynamic simulator modify these signals for change in perspective. Examples of systems developed/proposed utilizing this technique are as follows:

a. Dalto Scanalog Visual Attachment

b. Link Night Landing Display

c. Marquardt-Pomona Multi-Channel Memory System (MCM)

d. Goodyear Snythetic Image Data Generation (SIDG)

C. Evaluation Method

The method of evaluation of each simulation technique consists of rating from 0 to 2 (0=poor, 1=fair, 2=good) the extent to which each of the major techniques is judged to meet each criterion. A rating system for evaluating techniques was selected for two reasons:

1. Most major techniques involve two or more modes and visual attachment systems constructed around each technique differ considerably among themselves. As a consequence, any attempt to refine the method of evaluation beyond a relatively simple rating form would be meaningless.

2. This study covers a relatively broad scope at a general level because of the large number of diverse content areas. In implementing this approach treatment of the visual simulation industry at the technique level is appropriate.

The first part of the evaluation sequence involves the assessment of the techniques against criteria established in Section IV of the report. Questions remain as to the relative importance of these criteria. The procedure selected for weighting the criteria is fairly simple and consists of utilizing three guidelines:

1. Any technique was eliminated from further consideration which did not receive a rating of at least 1 on all of the required physical fidelity criteria.

2. As a general procedure, any technique was eliminated from further consideration which did not receive a rating of at least 1 on all of the required perceptual fidelity criteria. In special cases, it was decided to retain any technique for further consideration which received a rating of 0 (poor) on any of the required perceptual fidelity criteria if two conditions were judged to exist: (a) the variable class under question (receiving a rating of 0) could be designed into a visual attachment and be adequately simulated at least under certain restricted conditions; and (b) the technique reveals engineering state-of-the-art evidence of growth potential with regard to simulating perceptual properties of the variable under consideration.

3. Major emphasis was placed on equipment that satisfied research requirements, a necessary condition. Other major considerations (management and equipment operations and maintenance) would then be used to determine the feasibility and desirability of procuring a visual attachment that satisfied these requirements.

D. Evaluation of Techniques Against Physical Fidelity Criteria

There are two classes of problems which require physical fidelity. The detection/identification problems require physical fidelity in the simulation of photometric/colorimetric variables, ambient variables, and spatial variables. See Chart 5. The guidance problems require physical fidelity in the simulation of spatial variables and dynamic variables. Chart 7 shows the results of rating major state-of-the-art techniques in terms of meeting physical fidelity criteria.[1] The reader is directed to Appendix B which contains brief descriptions of the major considerations for applying the particular rating scores to each category in Chart 7. Inspection of the chart shows that none of the major industrial techniques reviewed meet the physical fidelity requirement for studying photometric/colorimetric variables, and only the Film technique reveals any existing state-of-the-art capability for simulating ambient conditions.[2] Section VI of this report identifies and describes alternative research study settings which are applicable for studying various aspects of the detection/identification problem area.

Chart 7 shows that three (3) of the techniques satisfy, at least minimally, the required physical fidelity for investigating problems in the area of guidance; namely, Direct Viewing, Closed Circuit Television, and Synthetic Image Generation. These three techniques are further evaluated below with respect to perceptual fidelity and simulator requirements.

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1. Because of the wide differences in the capabilities of the two modes used in the Optical technique (Diascopic and Epidiascopic), separate evaluations are made for each major variation of the technique.

2. This does not mean that lights of different colors and brightness cannot be simulated in visual attachments. In fact, problems of guidance have been studied using different colored lights to code the lighting pattern (43). It does mean that the study of the photometric and colorimetric properties of lights and objects is not feasible within the current state-of-the-art.

CHART 7: RATING MAJOR STATE-OF-THE-ART OF VISUAL ATTACHMENT TECHNIQUES IN TERMS OF MEETING PHYSICAL FIDELITY CRITERIA

0 = Poor, 1 = Fair, 2 = Good

	Physical Fidelity Criteria				
Visual Attachment Technique	Photometrics/ Colorimetrics	Ambient	Spatial	Dynamic[1]	Total
Pictorial Element Computation	0	0	1	0	1
Film	0	1	2	0	3
Direct Viewing	0	0	2	1	3
Optical (Diascopic)	0	0	0	0	0
Optical (Epidiascopic)	0	0	0	1	1
Closed Circuit Television	0	0	2	1	3
Synthetic Image Generation	0	0	1	1	2
TOTAL	0	1	8	4	

1. Unprogrammed "closed loop" mode.

E. Evaluation of Techniques Against Perceptual Fidelity Criteria

There are two remaining classes of problems which require perceptual fidelity. The guidance problems require perceptual fidelity in the simulation of brightness/color contrast variables and ambient variables. The pilot related problems require perceptual fidelity in the simulation of brightness/color contrast variables, atmospheric representation, object/contour representation, and apparent motion perspective. Chart 8 shows that the technique of Direct Viewing adequately meets the perceptual fidelity requirements for both the guidance and pilot areas. The Film technique satisfies perceptual fidelity requirements for the pilot problem areas. Closed Circuit Television and Synthetic Image Generation meet the requirements for perceptual fidelity in atmospheric representation but are rated as poor in simulating perceptual fidelity in the brightness and color contrast category. Perceptual fidelity of the Closed Circuit Television and Synthetic Image Generation displays are restricted to low illumination and low visibility ranges. However, since perceptual fidelity is possible in the area of brightness/color contrast under low illumination ranges and since the demonstrated rate of technological development in Closed Circuit Television is quite rapid (3), the two conditions specified earlier with regard to a rating of 0 (in the perceptual fidelity area) have been satisfied. In summary, Direct Viewing, Synthetic Image Generation, Film, and Closed Circuit Television possess, with some limitations, state-of-the-art capabilities for studying research problems associated with guidance and pilot variables.

CHART 8: RATING MAJOR STATE-OF-THE-ART VISUAL ATTACHMENT TECHNIQUES IN TERMS OF MEETING PERCEPTUAL FIDELITY CRITERIA

0 = Poor, 1 = Fair, 2 = Good

	Perceptual Fidelity Criteria				
Visual Attachment Technique	Brightness and Color Contrast	Atmospheric Representation	Object/Contour Representation	Apparent Motion Perspective[1]	Total
Pictorial Element Computation	1	0	1	0	2
Film	2	2	2	2	8
Direct Viewing	2	1	2	1	6
Optical (Diascopic)	1	0	0	0	1
Optical (Epidiascopic)	0	0	1	1	2
Closed Circuit Television	0	2	2	1	5
Synthetic Image Generation	0	1	1	1	3
TOTAL	6	6	9	6	

1. Unprogrammed "closed loop" mode.

F. Evaluation of Techniques Against Other Criteria

The Direct Viewing technique which has most adequately satisfied the visual simulation criteria shows a rating of 0 in Chart 9 with regard to the research requirements for flexibility. The flexibility requirement is essential when studying problems of guidance cues during flight and ground terminal operations. Because of the importance of flexibility, the Direct Viewing technique is not considered suitable as a research media for guidance problems. On the other hand, pilot related problems do not particularly require as much flexibility since the referent of interest is personnel and not marking and lighting configurational systems. The manipulations that are made are done with personnel and not with configurational patterns.

The Film technique rates poorly in the requirement for measurability. However, with pilot related problems, measurability would be primarily confined to flight track deviations, time measures, procedural errors, and pilot verbal responses and not to the variables being visually simulated. Using this concept of measurability, it is technically feasible to develop and attach data recording devices within the context of the Film technique.

The Closed Circuit Television technique rates poorly in terms of flexibility and measurability. For the reasons given above, the Closed Circuit Television technique warrants further consideration for studying pilot variables but not guidance variables.

The Synthetic Image Generation technique is rated as adequate or better than adequate in terms of meeting research criteria. Consequently, this technique shows the greatest promise as a research tool for studying guidance problems. With regard to pilot problems, the Synthetic Image Generation technique has a considerably lower overall rating on perceptual fidelity than the other three techniques discussed above. (Perceptual fidelity is the major criterion in studying pilot variables). See Chart 8. The

CHART 9: RATING MAJOR STATE-OF-THE-ART VISUAL ATTACHMENT TECHNIQUES IN TERMS OF MEETING MANAGEMENT, EQUIPMENT, AND RESEARCH CRITERIA

0 = Poor, 1 = Fair, 2 = Good

	Management Criteria			Equipment Criteria			Research Criteria			
Visual Attachment Technique	Cost	Growth Potential	Packageability	Compatibility	Durability	Maintainability	Flexibility	Measurability	Reliability	TOTAL
Pictorial Element Computation	0	2	2	0	1	1	0	1	2	9
Film	1	0	2	1	2	2	1	0	2	11
Direct Viewing	1	2	1	1	2	2	0	1	1	11
Optical (Diascopic)	2	0	1	1	2	2	0	0	1	9
Optical (Epidiascopic)	2	0	1	1	1	1	0	0	1	7
Closed Circuit Television	2	1	0	2	2	2	0	0	1	10
Synthetic Image Generation	0	2	2	2	2	1	2	1	1	13
TOTAL	8	7	9	8	12	11	3	3	9	

Synthetic Image Generation technique should either be eliminated from consideration as a suitable simulation technique for studying pilot problems, or at best, considered very marginal in this area. The major capability of this technique is in the guidance area. Attempting to develop a single visual attachment which simultaneously meets the needs of the guidance problems and the pilot problems might well lead to a series of compromises which would result in a visual attachment which did not meet any of the requirements or criteria very well.

In summary, none of the existing visual simulation techniques are judged to meet the physical fidelity criteria needed to effectively study research problems in the detection/identification area. The only technique which showed significant promise as a research tool for studying problems involving dynamic guidance tasks is the Synthetic Image Generation technique. Three techniques are possibilities as the basis around which to construct a visual attachment for studying pilot related problems, i.e., Film Direct Viewing, and Closed Circuit Television.

VI. Research and Development Cycle and Study Settings

A. Introduction

In Section I, it was pointed out that this study represents a segment of a planned research problem within the human factors area. The ultimate objective of this program is to achieve the most efficient combination of study setting techniques at a reasonable capital outlay to accelerate research and control in investigating problems involving visual aids, cockpit displays, and significant pilot problems. The need for such a program stems from the rapid growth of U. S. aviation and its demands on aviation support facilities and pilot performance requirements. As a consequence, timely research information is needed to aid in making effective decisions regarding human factors problems.

Within the framework of this objective,a proposed outline of a solution is presented, a solution which attempts to provide general but useful guidelines for selecting research settings judged as being suitable for investigating human factors problems at different stages in an R & D cycle.

At least four considerations determine the choice of settings to investigate problems such as the thirty (30) listed in Charts 1, 2, and 3 of Section III.

1. The purpose of the study or type of information required.
2. The nature of the problem or phenomena being investigated.
3. The effectiveness with which a study setting provides the context and conditions required, i.e., fidelity requirements for the variables being investigated.

4. The efficiency with which a study setting can provide the information required, e.g., cost and time factors, control, safety, etc.

This section discusses these considerations within the context of a research and development cycle and identifies and describes research settings appropriate to investigate problems associated with visual cues and pilot performance.

B. Comments on the R & D Cycle

The research and development cycle of a system commonly connotes stages in design and development of a complex weapon, sensor system, or some other system, with equipment as the core of the system around which men and procedures are integrated (8, 54). In practice, it seems that this connotation is more often adhered to than not. Systems are normally referenced to the equipment rather than to its objective or function, e.g., the Polaris system. But the concept of an R & D cycle has a much broader base of meaning. In essence, the stages of an R & D cycle are appropriate as guidelines whenever an attempt is made to find an operationally feasible solution to any complex problem involving the integration of men, equipment, and procedures. The nature of the solution need not consist of the design of a new piece of equipment but may involve the development of a new operational concept or even a new training program.

Furthermore, the stages in an R & D cycle guide research toward solving existing problems as well as toward satisfying projected requirements.[1]

Within this concept, the R & D cycle consists of four major stages:

1. Requirement Stage: Requirements are established by comparing existing or projected performance requirements with existing capabilities. A significant discrepancy indicates a requirement--a problem area to be studied. Delineation of the magnitude and nature of these problem areas along with a description of requirements are the outputs of this stage.

2. Design and Development Stage: The objective of this stage is to construct a tentative solution to the problem area(s). The nature of the solution and the setting in which the solution is developed need not be equipment oriented. The solution proposed may consist of an operational concept, a new organization, or improved procedures for selecting and training operators. Frequently the proposed solution combines new operational concepts, development of new equipment, and the development of a new program of personnel selection and training. Studies performed during this stage provide information so that decisions can be made among alternative solution possibilities. The output of this stage is a proposed solution designed to solve the existing or projected problem or requirement.

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1. The concept of operations research is normally confined to the identification of problems and development of appropriate solutions within the context of existing systems (22). Systems research, on the other hand, is generally considered as a combination of research techniques and procedures dealing with the development of a new system to solve projected requirements (14). Within the context of this report, both approaches are included in the framework of an R & D cycle.

3. Testing Stage: The proposed solution is subjected to various types of testing to determine whether, in fact, the solution meets the requirements established in Stage 1. Normally, the solution is checked in terms of its operational feasibility, equipment adequacy, and availability of personnel capable of implementing the proposed solution. The output of this stage is a tentatively approved solution which meets intermediate performance criteria under controlled testing conditions.

4. Operational Stage: The solution is integrated into the operational context, e.g., a civil airport, an aircraft, or even a standardized pilot test and evaluation procedure. Here the solution receives an operational type of evaluation. The objective during this stage is to determine the adequacy of the solution when operating under normal conditions or conditions for which the solution was designed. For example, it may involve the effectiveness of an airport beacon in fog conditions that occur very seldom. The expected output of this stage is an operationally acceptable solution to the requirements established in Stage 1.

This concept of an R & D cycle is used as the context for examining the various considerations which bear on the selection of an appropriate study setting.

C. Selection of a Study Setting

Using the stages of the R & D cycle as the basic frame of reference, the purpose of the study or type of information required may be one of four major types:

1. Requirements Information: The purpose of the study is to identify and/or better define present problems or projected requirements with regard to a referent system possessing a defined objective and an existing or assumed set of capabilities.

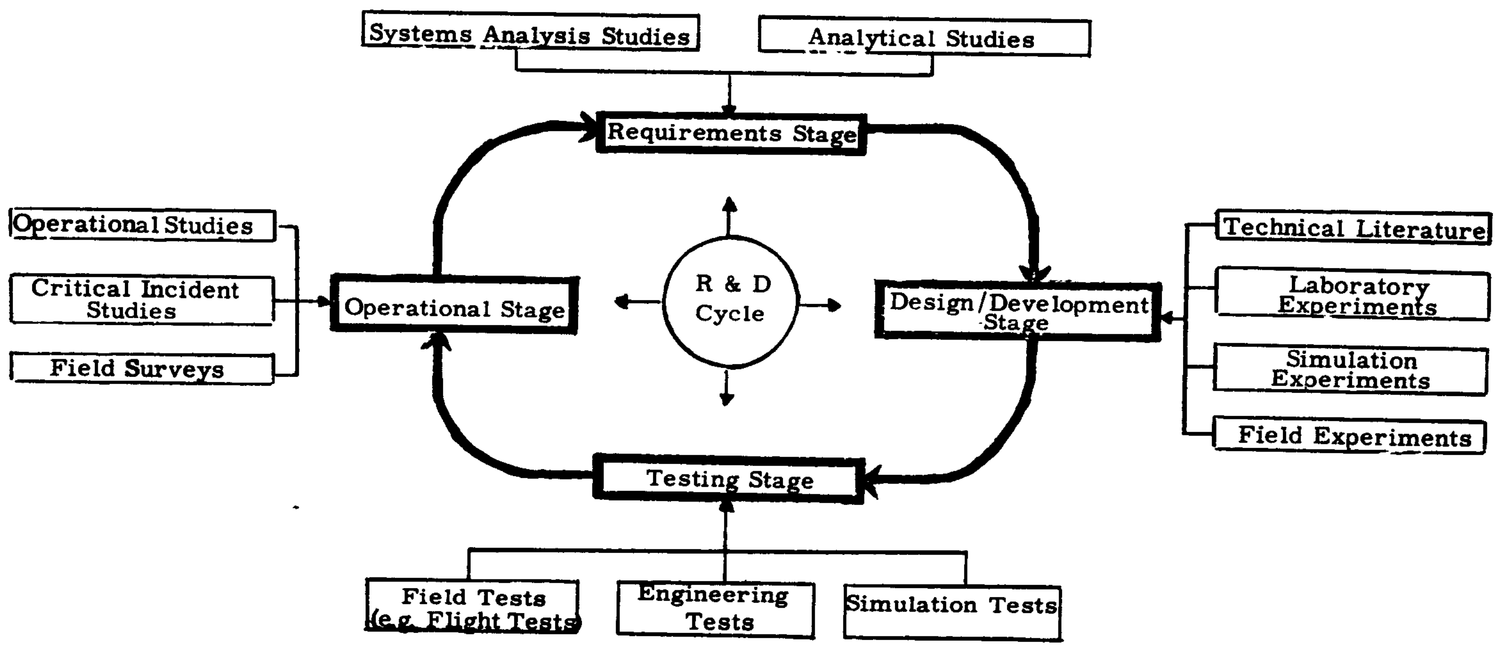
2. Design and Development Information: The purpose of the study is to design and develop solutions to the problems or stated requirements and to obtain pertinent information which contributes to that cbjective.

3. Testing Information: The purpose of the study is to determine the effectiveness of a proposed solution by testing, generally under controlled conditions, varous aspects of the solution. Depending on the type of solution developed (operational concepts, materiel development, personnel capabilities), the testing media will be appropriately selected to fit the nature of the proposed solution.

4. Operational Information: The study would determine the effectiveness of the proposed solution when integrated into the operational context. It is important to check and solve, if necessary, any problems involved in incorporating the solution into an existing system.

Figure 2 graphically illustrates the major four stages in the R & D cycle and lists representative study settings and research or study techniques commonly associated with each of these stages. By classifying the purpose of the study in terms of the four major types of information required (i.e., consideration number 1, cited under heading A) it is possible to place the study objective within the R & D cycle and to specify the range of study settings and techniques appropriate to this stage.

FIGURE 2: RELATING THE R & D CYCLE TO STUDY SETTINGS AND TECHNIQUES



The second consideration, for selecting an appropriate study setting requires a delineation of the nature of the problem or phenomena requiring investigation (Refer to the list of 4 considerations under heading A). In this study the problems are classified as primarily involving either detection/identification tasks, guidance tasks, or the effects of pilot variables on the pilot's ability to effectively utilize available visual cues during terminal operations. Utilization of this consideration in selecting appropriate research settings is shown in Chart 10 at the end of this section. Implementing this consideration is treated in Chart 11 at a fairly broad level. Although it is beyond the scope of this report, it would be possible to further subdivide the nature of the problems into even more detailed levels. Identification of the tasks involved provides a basis for determining the requirements for simulation within a study setting as well as test procedures required.

The third consideration concerns the effectiveness with which a study setting provides the appropriate context and conditions for investigating the variables involved. Earlier sections of this report discussed the third consideration with respect to "real world" visual attachments to dynamic flight simulators. Identifying that the problem primarily involves a detection/identification task or some other task is only part of the overall requirement. It is also necessary to determine the context and conditions under which the task will be investigated. This involves obtaining information regarding the conditions and situation from which the problem originated, i.e., type and nature of airport and airport area, ambient factors, relevant aircraft and aircraft characteristics, particular flight or ground phase, and airport marking and lighting facilities involved, if any. Information pertinent to the conditions was briefly discussed in Section I and amplified in greater detail in Section II of this report. In Section III the major conditions associated with each problem area were identified. Identification of the conditions and situation serves to specify which variables should be studied and at what values.

The fourth consideration concerns the efficiency with which a given study setting provides the information required. Efficiency may be roughly defined as the amount of useful information obtained relative to the cost required to obtain this information. Useful information considerations are made up of such elements as reliability, completeness, and accuracy of the output information. Cost includes such considerations as time, money, personnel, and safety requirements. The list of equipment requirements and criteria presented in Chart 9 identifies many of the considerations which are involved in selecting an efficient study setting. Chart 11 lists assumed efficient research settings for the three groupings of thirty (30) problems shown in Charts 1, 2, and 3.

D. Representative Types of Study Settings

Let us consider some of the characteristics of study settings that can be used to investigate various problems involving visual cues. See the list of study settings and techniques illustrated in Figure 2.

Chart 10 identifies five (5) major study settings and some of the major variants within each study setting. Study settings I, II, IIIA, and IVA are associated with the design and development stage. These study settings primarily provide information contributing to the development of a solution to a given problem. One or more of these study settings may be selected to provide the required information. Laboratory study settings generate information regarding basic visual capabilities and limitations of the human. Static and dynamic open loop study settings (i.e., II) provide information using "real world" stimulus properties that are related to the operational environments. It might be noted that both study settings II and IVA contribute information appropriate to the detection/identification area. See Chart 11. Study setting IIIA provides design input information regarding guidance effectiveness of various geometric configurations.

Study settings, IIIB and IVB are associated with the testing stage in the R & D cycle. These study settings are designed to determine the comparative effectiveness of different proposed solutions or the level of effectiveness of a proposed solution against some pre-established performance standards. Study settings VA and VB are associated with the operational stage. These study settings are designed to determine the operational effectiveness of approved solutions.

E. Utilization of the Study Setting Classification

The information contained in Chart 10 is necessarily quite general. However, to provide some operational meaningfulness to the classification, Chart 11 illustrates the study settings appropriate for problems in detection/identification, guidance, and pilot areas during different stages in the R & D cycle. Chart 11 reveals the application of the four considerations listed at the beginning of this section to the task of selecting appropriate research settings.

To further amplify the utilization characteristics of the study setting classification procedure or index, a sample of six recently completed or ongoing research studies on visual cues are assigned to appropriate settings. See Appendix C. The material in Appendix C contains six examples. Within the appendix the reference or source is cited, the study setting index is given, a description of the study and/or setting is presented, and results and comments are included.

CHART 10: CLASSIFICATION AND ELABORATION OF STUDY SETTINGS APPROPRIATE TO VISUAL SIMULATION STUDIES

Study Setting	Visual Presentation Methods	Independent Variables	Dependent Variables	Nature of Information
I LABORATORY	A. Incident Light Manipulation of the physical optical properties of light and its temporal and spatial characteristics	Adaptation Intensity Wavelength Duration Change Rate of Change Stimulus Area	Sensory Discrimination Threshold Measures	Quantitative and qualitative relationships between the physical optical properties of light and human visual capability. Information contributes to design of lights for all conditions.
	B. Reflected Light Manipulation of figure/surface relationships and figure/figure relationships	Brightness Contrast Color Contrast Shape Differences Size Differences Change Rate of Change Stimulus Area	Sensory and Perceptual Discrimination Threshold Measures	Information on the sensitivity of the human to discriminate differences between object/ground and object/object characteristics under various contrast conditions. Contributes to such problems as runway reflectivity.
II STATIC AND DYNAMIC (programmed "open loop") SIMULATION	A. Transparencies (Slides/Film) Color and black/white slides or films of real world or simulated real world objects taken in different situations and under various ambient conditions	Type(s) of Object(s) Number of Objects Location of Objects Ambient Conditions Ground Characteristics Dynamic Conditions	Detection and Identification Measures under Static and Dynamic Conditions	Human capability to detect and identify real world or simulated real world objects under various spatial, dynamic, ambient and ground conditions. Contributes to such problems as obstacle avoidance lights, height information, etc.
	B. Models (Scaled) Manipulation of scaled models of objects and light properties of the real world under various ambient and background conditions	Types of Models Distribution of Models/Lights Number of Models Physical Properties of Models Ambient Conditions Background Conditions Dynamic Conditions	Judgments of distance, speed, position and direction of the observer relative to the models and ground	Information on the utility value of various apparent movement and object/light cues in locating the position, direction, speed, and distance of the observer with respect to the objects/lights and surface characteristics

CHART 10 (continued)

Study Setting	Visual Presentation Methods	Independent Variables	Dependent Variables	Nature of Information
III STATIC AND DYNAMIC (unprogrammed "closed loop) SIMULATION	A. Analog (Abstract) Simulation Manipulation of configurational (geometric) properties of ground contours/objects in analog or abstract form	Angular and Linear Separation of Objects Directional Alignment of Objects Configurational Characteristics	Diagnostic Performance Measures of Translational and Rotational Status over Time: a. Deviation and Displacement Measures b. Accuracy Measures c. Time Measures d. Error Frequency	Design criteria relating guidance properties of object/ground configurations to the dynamic characteristics of aircraft and human discrimination capability
	B. Real World Simulation Screening (testing) of proposed or developed configurational designs within a simulated real world context for providing guidance cues during various terminal operations	Proposed or developed object/light configurations designed to provide specific guidance cues during one or more flight/ground phases	Integrated Performance Measures Supplemented by Pilot Judgments a. RMS Tracking Errors b. Time to Completion/Correction c. Integrated Work Functions (Control Actions)	Comparative performance superiority of one configurational design over others or the absolute level of flight performance attributed to a design when compared against a pre-established criterion; also, consensus of pilot opinion/judgments with regard to one or more proposed, developed, or existing designs

CHART 10 (continued)

Study Setting	Visual Presentation Methods	Independent Variables	Dependent Variables	Nature of Information
IV FIELD (Static and Dynamic)	A. Field Experiments Manipulation/selection of photometric, colorimetric properties of lights or configurational characteristics of objects to determine their identification and/or guidance cue providing capabilities	Photometric and colorimetric properties of signs/markings and lights; Configurational characteristics of lights/markings, aircraft type; Ambient conditions (selected or simulated) Flight/ground phases	Diagnostic Performance Measures of Rotational and Translational Status over Time. a. Deviation and Displacement Measures b. Accuracy Measures c. Time Measures d. Error Frequency	Design criteria relating detection/identification and/or guidance properties of objects to the structural, spatial, and dynamic characteristics of aircraft and human capability
	B. Field Tests Testing the functional (cue providing) capability of prototype or developed marking and lighting components and their spatial arrangement	Prototype components Configurational designs Static/Dynamic Conditions Ambient conditions (selected or simulated) Flight/ground phases	Integrated Performance Measures Supplemented by Pilot Judgments a. RMS Tracking Errors b. Time to Completion/Correction c. Integrated Work Functions (Control Actions)	Comparative or absolute performance levels of proposed or developed components and systems in providing identification/guidance cues during one or more flight/ground phases

CHART 10 (continued)

Study Setting	Visual Presentation Methods	Independent Variables	Dependent Variables	Nature of Information
V	A. Critical Incident Studies Accident and near-accident data obtained by interviewing pilots to determine the probable reasons for these events as they reflect on the question of safety	The occurence of accidents or near-accidents provides the basis for obtaining information pertinent to the functional effectiveness of external or cockpit visual cues.	Descriptions by the pilot of the conditions and events which occurred	Hypotheses are developed for further study to verify and then eliminate marking/ lighting conditions which are potentially detrimental to safety
AIRPORT OR TERMINAL AREA (Operational Environment)	B. Operational Analysis Techniques Recording/measuring both aircraft performance and airport cost indices as they reflect on the functional efficiency of marking and lighting systems	Normal variations in air/ground traffic, ambient conditions, and aircraft mix in the terminal area provide a range of conditions whicn can be recorded and described.	Both aircraft performance measures during terminal operations and cost measures available for recording. Performance summed over many aircraft flights and conditions.	Indices of efficiency are generated which provide information regarding the operational feasibility of a solution or solutions, i.e., operationally validating a solution.

CHART 11: ASSIGNMENT OF STUDY SETTINGS TO DETECTION/IDENTIFICATION/GUIDANCE PILOT PROBLEM AREAS DURING DIFFERENT R & D STAGES

	Classification of Problem Areas		
R & D Stage[1]	Detection/Identification	Guidance	Pilot
Design and Development Stage	Laboratory: Absolute and Differential Visual Thresholds IIA. Transparencies: Object Detection and Identification Thresholds IIB. Models: Location, Distance, Dynamic Movement Thresholds IVA. Field Experiment: Detection/Identification of Lights/Marking Variations under Ambient Conditions	Laboratory: Discrimination Thresholds IIIA. Analog Simulation: Sensitivity to Variations in Translational/Rotational Changes Using Visual Pattern Information IVA. Field Experiment: Guidance Effectiveness of Variations in Geometric Alignment and Spacing of Observable Objects/Lights	Laboratory: Information on Variability of Basic Visual Capabilities of Man under a Wide Range of Experimental Conditions
Testing Stage	IVB. Field Tests: Detection/Identification Effectiveness of Proposed Marking and Lighting Components or Systems under Conditions for Which Solution Was Designed	IIIB. Real World Simulation: Comparative Guidance Effectiveness of Proposed Alternative Solutions IVB. Field Tests: Guidance Effectiveness of Selected Lighting and Marking Patterns under Conditions for Which Solution Was Designed	IIA. Transparencies: Speed and Accuracy of Detection/Identification of Objects/Complexes IIIB. Real World Simulation: Relative Effectiveness of Pilots to Fly Prescribed Flight Patterns and Perform Cockpit Procedures IVB. Field Tests: Performance Effectiveness of Pilots to Perform Prescribed Flight/Procedural Tasks

1. Requirements Stage normally involves study techniques other than visual study settings. Operational Stage includes contributions and operations of all aspects related to flight performance of pilots since controls and systematic variations are normally not introduced.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Aeronautical Research Foundation and Cornell Aeronautical Laboratory, Airborne Instruments Laboratory. National requirements for aviation facilities 1956-1975. Volume I, Summary. Washington, D. C.: Author, May 1957.

2. Baldwin, R. D., & Wright, A. D. An attempt to develop a radar operator screening test: A report of simulator instability. Fort Bliss, Tex.: U. S. Army Air Defense Human Research Unit and The George Washington University Human Resources Research Office, June 1962.

3. Buddenhagen, T. F., & Wolpin, M. P. A study of visual simulation techniques for astronautical flight training. Wright-Patterson Air Force Base, Ohio: Behavioral Sciences Laboratory, March 1961. (WADD Technical Report 60-756, Contract No. AF 33(616)-7028).

4. Calcagno, J. Feasibility study for a fog simulator. Phase II. Binghamton, N. Y.: Link Aviation, Inc., November 1959. (Contract No. FAA/BRD-50).

5. Calvert, E. S. Visual aids and their effect on landing success and safety. Farnborough, Eng.: Royal Aircraft Establishment, October 1955.

6. Coleman, H. J. A human factors study of the integrated visual approach and landing aids (IVALA) system. Eglin Air Force Base, Fla.: Air Research and Development Command, Air Proving Ground Center, December 1959. (APGC-TR-59-52).

7. Creelman, J. A. Evaluation of approach training procedures. Pensacola, Fla.: U. S. Naval School of Aviation Medicine, Naval Air Station, October 17, 1955. (Report No. 2, Research Project NM 001 109 107).

8. Davis, R. H., & Behan, R. A. Evaluating system performance in simulated environments. In R. M. Gagne (Ed.), Psychological principles in system development. New York: Holt, Rinehart and Winston, 1962.

9. Federal Aviation Agency. Project Beacon. Report of task force on air traffic control. Washington, D. C.: Author, October 1961.

10. Federal Aviation Agency. Research and development program and progress report. Washington, D. C.: Author, November 1958.

11. Federal Aviation Agency. Research and development program and progress report. Washington, D. C.: Author, September 1959.

12. Federal Aviation Agency, Aviation Research and Development Service, Research Division. Quarterly progress report, fourth quarter, FY 61. Part III, Human Factors Branch. Atlantic City, N. J.: Author, December 1961.

13. Federal Aviation Agency, Bureau of Research and Development. Research and development progress report, April 1961. Washington, D. C.: Author, April 1961.

14. Finan, J. L. The system concept as a principle of methodological decision. In R. M. Gagne (Ed.), Psychological principles in system development. New York: Holt, Rinehart and Winston, 1962.

15. Frey, R. B., & Havron, M. D. An analysis of the helicopter pilot's landing task. Arlington, Va.: Human Sciences Research, Inc., November 1961. (HSR-RR-61/16-Mk-X, Contract No. FAA/BRD-401).

16. General Electric, Light Military Electronics Department. Human factors on ANIP. Utica, N. Y.: Author, June 1961. (Final Report, Contract No. Nonr 1076 (00), ASTIA Document No. AD 239 527).

17. Gibson, J. J., Olum, P., & Rosenblatt, F. Parallax and perspective during aircraft landings. Amer. J. Psychol., 1955, 68 (3), 372-385.

18. Gilinsky, A. S. Perception of size of objects at various distances. Lowry Air Force Base, Col.: Air Research and Development Command, Air Force Personnel and Training Research Center, December 1954. (AFPTRC-TR-54-92, ASTIA Document No. AD 63041).

19. Gogel, W. C. Relative visual direction as a factor in depth perceptions in complex situations. Fort Knox, Ky.: Army Medical Research Laboratory, November 9, 1954. (Report No. 148, AMRL Project No. 6-95-20-001, ASTIA Document No. 51231).

20. Goldstein, A. H. Judgments of visual velocity as a function of length of observation time. Fort Knox, Ky.: Army Medical Research Laboratory, Psychology Department, May 24, 1956. (Report No. 239, AMRL Project No. 6-95-20-001, ASTIA Document No. AD 109 229).

21. Graham, C. H. Visual perception. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: John Wiley & Sons, Inc., 1951.

22. Harling, J. Simulation techniques in operations research--a review. J. oper. res. Soc. Amer., 1958, 6 (3), 307-319.

23. Havron, M. D. Information available from natural cues during final approach and landing. Arlington, Va.: Human Sciences Research, Inc., March 1962. (HSR-RR-62/3-Mk-X, Contract No. FAA/BRD-401).

24. Human Factors Operations Research Laboratories and Personnel Research Center, Inc. Flight simulator utilization handbook. Bolling Air Force Base, Washington, D. C.: Author, August 1953. (HFORL Report No. 42).

25. Human Factors Research Branch, Research Division. Functional statement. Atlantic City, N. J.: Federal Aviation Agency, Bureau of Research and Development, (no specified date).

26. Human Sciences Research, Inc. Description of future helicopter mission requirements as criteria for display evaluation. Arlington, Va.: Author, May 1960. (HSR-RP-60/9-Be).

27. Jenkner, K. W. Feasibility study for a fog simulator. Binghamton, N. Y.: Link Aviation, Inc., April 1959. (Contract No. FAA/BRD-50).

28. Jenkner, K. W. Feasibility study for a fog simulator. Phase III. Binghamton, N. Y.: Link Aviation, Inc., October 1961. (Contract No. FAA/BRD-50).

29. Judd, D. B. Basic correlates of the visual stimulus. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: John Wiley & Sons, Inc., 1951.

30. Lane, J. C., & Cumming, R. W. The role of visual cues in final approach and landing. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, May 1956. (Human Engineering Note 1).

31. Lear Incorporated, Grand Rapids Advance Engineering Division. Whole panel control-display study. Summary report, July 1958-July 1960. Volume II: The Mark IV control-display system. Wright-Patterson Air Force Base: Wright Air Development Division, July 1960. (Lear Engineering Report GR-1364 (II), WADD Technical Report, Contract No. AF 33(616)-5901, Project No. 6190).

32. Ludvigh, E., & Miller, J. W. The effects on dynamic visual acuity of practice at one angular velocity on the subsequent performance at a second angular velocity. Pensacola, Fla.: Kresge Eye Institute of Detroit and U. S. Naval School of Aviation Medicine, June 1, 1955. (Joint Project Report No. 9, Contract No. Nonr-586(00), and the Bureau of Medicine and Surgery Project No. NM 001 110 501.09).

33. Ludvigh, E., & Miller, J. W. The results of testing the dynamic visual acuity of 1000 Naval aviation cadets. Pensacola, Fla.: Kresge Eye Institute of Detroit and U. S. Naval School of Aviation Medicine, August 10, 1956. (Joint Project Report No. 10, Contract No. Nonr-586(00), and the Bureau of Medicine and Surgery Project No. NM 001 110 501).

34. Lybrand, W. A., Vaughan, W. S., Jr., & Robinson, J. P. Airport marking and lighting systems, a summary of operational tests and human factors. Final Report. Arlington, Va.: Human Sciences Research, Inc., May 1959. (HSR-RR-59/1-Mk, Contract No. FAA/BRD-13).

35. Lybrand, W. A., Vaughan, W. S., Jr., & Robinson, J. P. Airport marking and lighting systems, a summary of operational tests and human factors. Final Report, Appendix, Selected Annotations, and Bibliography. Arlington, Va.: Human Sciences Research, Inc., May 1959. (HSR-RR-59/1-Mk, Contract No. FAA/BRD-13).

36. Lybrand, W. A., Vaughan, W. S., Jr., & Robinson, J. P. Airport marking and lighting systems, a summary of operational tests and human factors. Condensed Report. Arlington, Va.: Human Sciences Research, Inc., May 1959. (HSR-RR-59/6-Mk, Contract No. FAA/BRD-13).

37. Lybrand, W. A., Havron, M. D., Gartner, W. B., Scarr, H. A., & Hackman, R. C. Recommendations on simulation of extra-cockpit visual cues in contact flight transition trainers. Appendix II. Information collection instruments. Arlington, Va.: Psychological Research Associates, April 1957. (PRA Report 57-4, Contract No. AF 41(657)-69).

38. Lybrand, W. A., Havron, M. D., Gartner, W. B., Scarr, H. A., & Hackman, R. C. Simulation of extra-cockpit visual cues in contact flight transition trainers. Lackland Air Force Base, Tex.: Air Force Personnel and Training Research Center, February 1958. (TR-58-11, Contract AF 41(657)-69, ASTIA Document No. AD 152 123).

39. Lybrand, W. A., Havron, M. D., Gartner, W. B., Scarr, H. A., & Hackman, R. C. Simulation of extra-cockpit visual cues in contact flight transition trainers. Appendix I. Lackland Air Force Base, Tex.: Air Force Personnel and Training Research Center, February 1958. (TR-58-11, Contract AF 41 9657)-69, ASTIA Document No. AD 152 123).

40. Lybrand, W. A. Special letter report for Aerojet proposal F-108 trainer-mission simulator visual simulation system human factors. Arlington, Va.: Human Sciences Research, Inc., August 1959. (HSR-RR-59/3-Jt).

41. Malouin, G. J. Proposal for an integrated visual landing system. Paper attached to International Air Transport Association Special Meeting, Amsterdam, November 14-22, 1955.

42. McIntosh, B. B., & Burke, J. M. Non-emergency landing accidents. Norton Air Force Base, Calif.: Directorate of Flight Safety Research, Office of the Inspector General, March 1957. (Publication No. 13-57).

43. McKelvey, R. K., Brown, G. S., & Ontiveros, R. J. Simulation comparison of three runway landing zone lighting patterns. Atlantic City, N. J.: Federal Aviation Agency, Bureau of Research and Development, April 1961. (Draft Report, Task 411-3-4R).

44. Mote, F. A., Grant, D. A., & Hoffman, G. K. The effect of brief flashes of light upon peripheral dark adaptation. J. exp. Psychol., 1961, 64 (Second half), 233-244.

45. Payne, T. A., Dougherty, D. J., Hasler, S. G., Skeen, J. R., Brown, E. L., & Williams, A. C., Jr. Improving landing performance using a contact landing trainer. Urbana, Ill.: University of Illinois, March 1, 1954. (Technical Report SPECDEVCEN 71-16-11, Astia Document No. AD 121 200).

46. Pondy, L. R. Available methods for evaluating man-machine systems. Columbus, Ohio: Battelle Memorial Institute, September 1959.

47. Randle, R. J., Jr., Vibration in helicopters: training considerations. Wright-Patterson Air Force Base, Ohio: Aero Medical Laboratory, March 1959. (WADC TN 59-61, Astia Document No. 212 314).

48. Rollins, W. F., & Vaughan, W. S., Jr. The criterion problem in flight tests of airport marking and lighting systems: a review. Arlington, Va.: Human Sciences Research, Inc., November 1961. (HSR-RR-61/15-Mk-X, Contract FAA/BRD-401).

49. Ronchi, V. Optics, the science of vision. New York: New York University Press, 1957.

50. Solley, C. M., & Murphy, G. Development of the perceptual world. New York: Basic Books, Inc., 1960.

51. Vaughan, W. S., Jr., Luce, T. S., & Kassebaum, R. G., Airport marking and lighting systems: a survey of operational tests and human factors, 1959-1961. Arlington, Va.: Human Sciences Research, Inc., October 1961. (HSR-RR-61/13-Mk-X, Contract No. FAA/BRD-401).

52. Virnelson, T. R., & Vaughan, W. S., Jr. Heliport lighting design solutions to pilot information requirements. Arlington, Va.: Human Sciences Research, Inc., December 1961. (HSR-RR-61/17-Mk-X, Contract No. FAA/BRD-401).

53. Weissman, N. W., Kassebaum, R. G., & Vaughan, W. S., Jr. Sensitivity to angular change as a function of retinal angle. Arlington, Va.: Human Sciences Research, Inc., May 1962. (HSR-RR-61/13-Mk-X, Contract No. FAA/BRD-401).

54. Whittenburg, J. A. Management supervision of the personnel area during weapon system development: a proposed concept. Arlington, Va.: Human Sciences Research, Inc., January 1962. (HSR-RR-62/1-Tn, Order No. 189/27441/62).

55. Whittenburg, J. A. Methodology for evaluation of a man-machine surveillance system. Arlington, Va.: Human Sciences Research, Inc., December 1959. (HSR-RM-59/26-Sm, Contract No. Nonr 2525-(00)).

56. Wise, J. E., & Whittenburg, J. A. Feasibility for research application of visual attachments for dynamic flight simulators. Report No. 1: State-of-the-art survey of the visual simulation industry. Arlington, Va.: Human Sciences Research, Inc., July 1962. (HSR-RR-62/7-Mk-X, Contract No. FAA/BRD-401).

APPENDIX A

Part I: U. S. Aviation Present and Projected Demands on Airport Facilities

A. Introduction

In developing specifications for a visual attachment to a dynamic flight simulator or, for that matter, developing specifications for any type of visual study setting, (e.g., field or laboratory) one of the prerequisites involves a determination of the operational context and conditions to be visually simulated. To satisfy this prerequisite, answers to three questions are required:

1. What is the nature of the operational context to be simulated?
2. What are the variables and conditions to be simulated?
3. What are the tasks required of the subjects, i.e., pilots?

The present and projected activities of U. S. aviation and the nature of the resulting demands placed on the nation's aviation facilities provide relevant background information for answering the above three questions. Part I of Appendix A presents a summary of background data and information covering the present and projected demands of U. S. aviation on airport facilities.

B. The Operational Context

Interviews with FAA personnel and examination of projections of air traffic demands (1, 9) indicate that most of the critical problems regarding air traffic and safety originate during terminal operations in major airport areas. A second major set of problems which is growing in significance and which will continue to do so stem from the demands placed on secondary airports (i.e., in towns with a population less than 100,000) to provide adequate navigational and visual aids for both IFR and VFR flight. Communities with secondary airports cannot afford developments being incorporated into major airports. As a consequence, a number of ongoing and planned research studies are aimed at the objective of designing and developing low cost but functionally adequate equipment systems and components for secondary airports.

With regard to major airports, it is a primary objective to increase the performance capabilities of the entire airport system by efficiently processing air and ground aircraft traffic. With regard to secondary airports, the primary objective is to provide the capability for safely processing aircraft under VFR and IFR conditions at a cost which is within reasonable bounds for the community. It may be assumed that solutions to problems surrounding these two extremes in airport size and air/ground aircraft traffic load will contribute useful information to the problems found in airports of intermediate sizes.

It is found that the critical operational contexts for investigating human factor problems associated with visual information to pilots during various flight phases is confined to terminal operations in major and secondary airports (as contrasted with enroute operations).

C. Operational Variables and Conditions

Table A-1 presents the number of terminal landing and take-off operations at airports in the United States. The data provide a measure of the magnitude of the demands placed on airport facilities during the period 1955 to 1975. In addition, it is possible to extract a measure of the rate of growth of each of the various types of demands. Both the magnitude and rate measures are useful in identifying those variables and conditions which are sufficiently important to study. The major classes of variables and conditions to be considered and compared include:

Aircraft Class: Rotary Wing vs. Fixed Wing Aircraft

Flight Conditions: IFR vs. VFR

Types of Aviation: Air Carrier vs. General Aviation

Types of Air Carrier and General Aviation Aircraft

A detailed classification of these variables and conditions may be found in Part II of this appendix. The data and information pertinent to these variables and operational conditions are presented below:

1. Aircraft Class (Rotary Wing vs. Fixed Wing Aircraft): The data in Table A-1 show that in 1960 terminal operations by helicopters accounted for about 9%, and fixed wing aircraft (combining general aviation, air carrier, and military) accounted for the remaining 91%. In 1975, helicopter terminal operations will account for about 14% of the total. The data clearly indicate that the great majority of terminal operations for the next several years will involve fixed wing aircraft.

Figure A-1 illustrates the comparative rate of growth in terminal operations of fixed wing vs. rotary wing aircraft during the period 1955 to 1975.[1] Only the data covering general aviation and air carrier aircraft were combined since terminal operations by military aircraft show a decline in magnitude during the period 1955 to 1975 and are not comparable to the steady growth predicted for both air carrier and general aviation aircraft. Inspection of Figure A-1 shows that the rate of projected growth for terminal operations by helicopters (rotary wing aircraft) is greater than for fixed wing aircraft.

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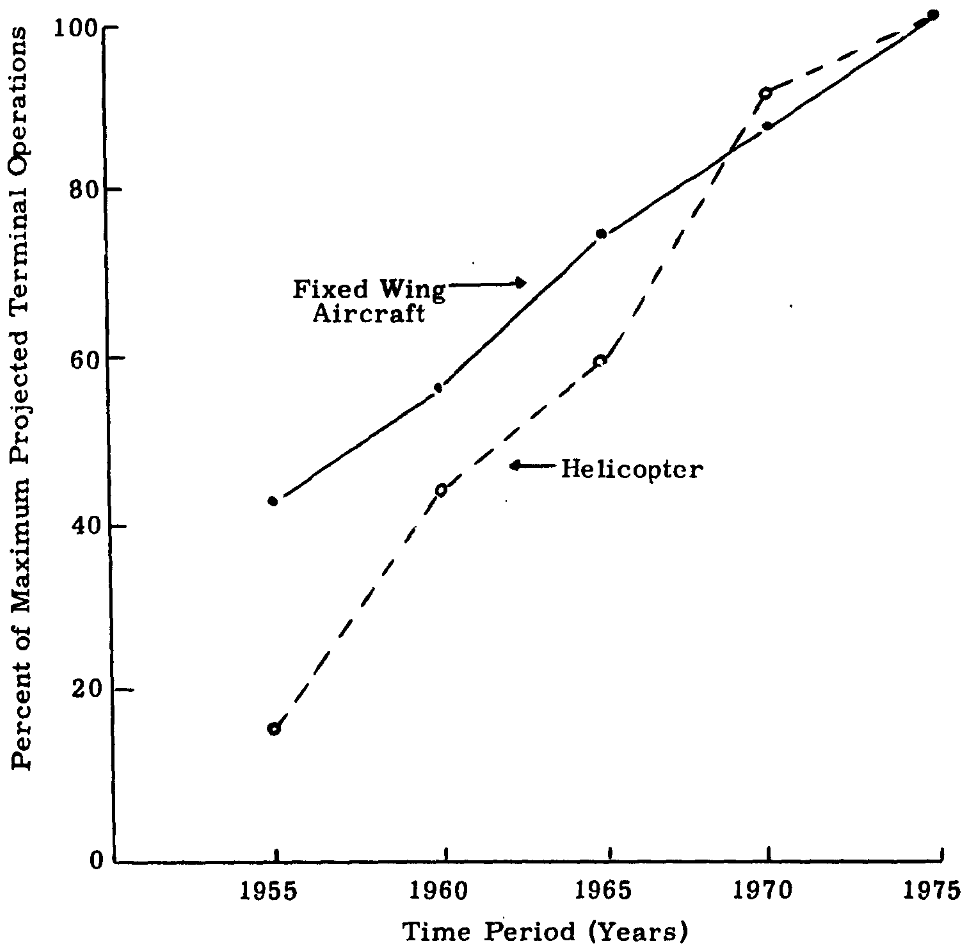
1. The percentages were computed by using the maximum number of projected terminal operations for each variable or condition as the 100% value. This procedure eliminates the effect that differences in numbers among the factors being compared would have on the graphic illustrations.

TABLE A-1: ANNUAL TERMINAL LANDING AND TAKE-OFF OPERATIONS[1]
(Millions of operations - actual and projected)

	1955	1960	1965	1970	1975
All Operations					
General Aviation	28.0	37.0	49.7	57.8	65.2
Air Carrier	6.5	8.0	9.8	11.9	14.1
Military	27.9	25.7	21.5	19.5	17.4
Total	62.4	70.7	81.0	89.2	96.7
IFR Operations					
General Aviation	0.3	0.6	1.0	1.5	2.2
Air Carrier	2.2	4.0	5.5	7.5	9.9
Military	1.8	2.3	2.0	1.8	1.7
Total	4.3	6.9	8.5	10.8	13.8
VFR Operations					
General Aviation	27.7	36.4	48.7	56.3	63.0
Air Carrier	4.3	4.0	4.3	4.4	4.2
Military	26.1	23.5	19.5	17.7	15.7
Total	58.1	63.9	72.5	78.4	82.9
Helicopter	2.5	6.7	9.1	13.9	15.2

1. See "Federal Aviation Agency. Project Beacon. Report of task force on air traffic control, a study of the safe and efficient utilization of airspace. Washington, D. C.: Author, October 1961."

FIGURE A-1: A GRAPHIC COMPARISON OF THE RATE OF INCREASE OF TERMINAL OPERATIONS FOR DIFFERENT AIRCRAFT TYPES[1]



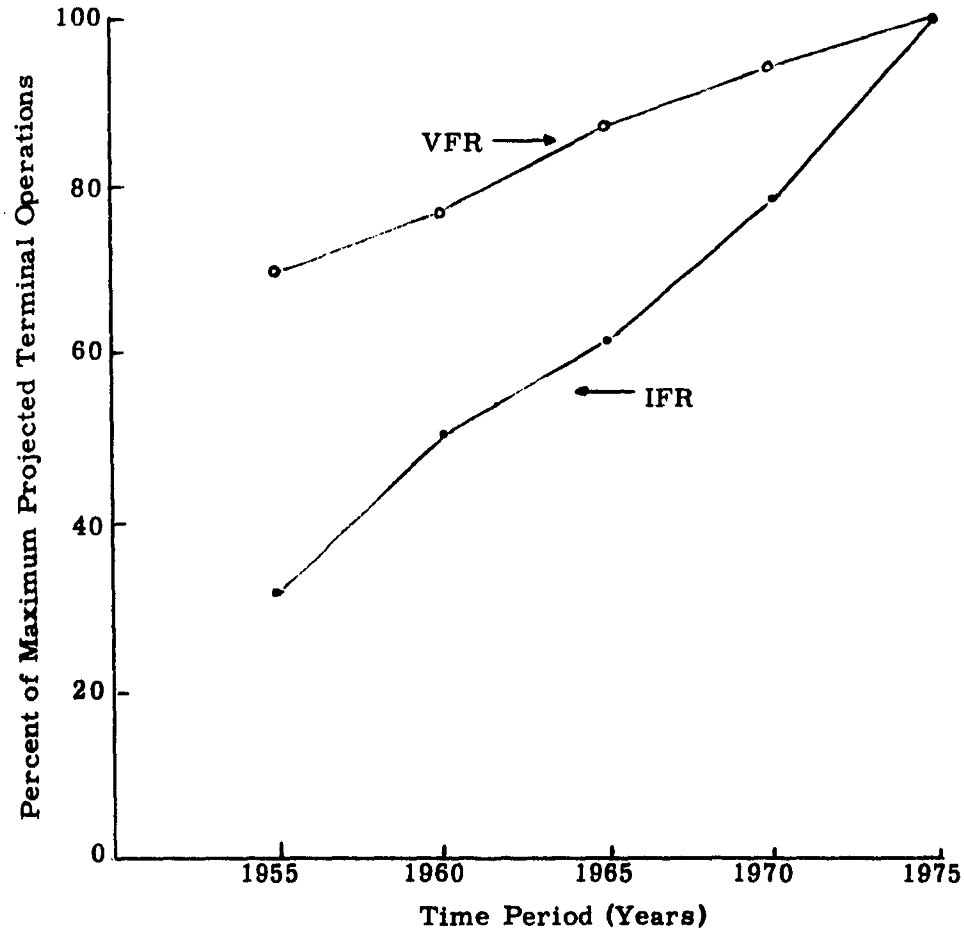
1. See "Federal Aviation Agency. Project Beacon. Report of task force on air traffic control, a study of the safe and efficient utilization of airspace. Washington, D. C.: Author, October 1961." Data for General Aviation and Air Carrier Aircraft were combined in determining the plotted fixed wing function.

2. <u>IFR vs. VFR Conditions</u>: The data in Table A-1 show that in 1960 terminal operations under IFR conditions accounted for about 10% and is projected to account for somewhat over 14% in 1975. Terminal operations under VFR conditions do and will continue to constitute the major bulk of terminal operations. However, Figure A-2 shows that the rate of growth of air traffic under IFR conditions is considerably faster than the rate of growth of terminal operations under VFR conditions.

3. <u>General Aviation vs. Air Carrier Aircraft</u>: The numbers in Table A-1 indicate that the 1960 terminal operations by air carrier aircraft will be the same, proportionately speaking, by 1975, i.e., 18% of the total. Figure A-3 shows that the rate of growth of general aviation aircraft under VFR conditions is considerably greater than for air carrier aircraft which reveals no observable rate of growth. Under IFR conditions both general aviation and air carrier aircraft operations in the terminal areas show about the same rate of projected growth. The major deductions that can be made from the available data are that general aviation aircraft will continue to be the dominant factor in terminal operations and will evidence a much faster rate of growth in VFR conditions than air carrier aircraft.

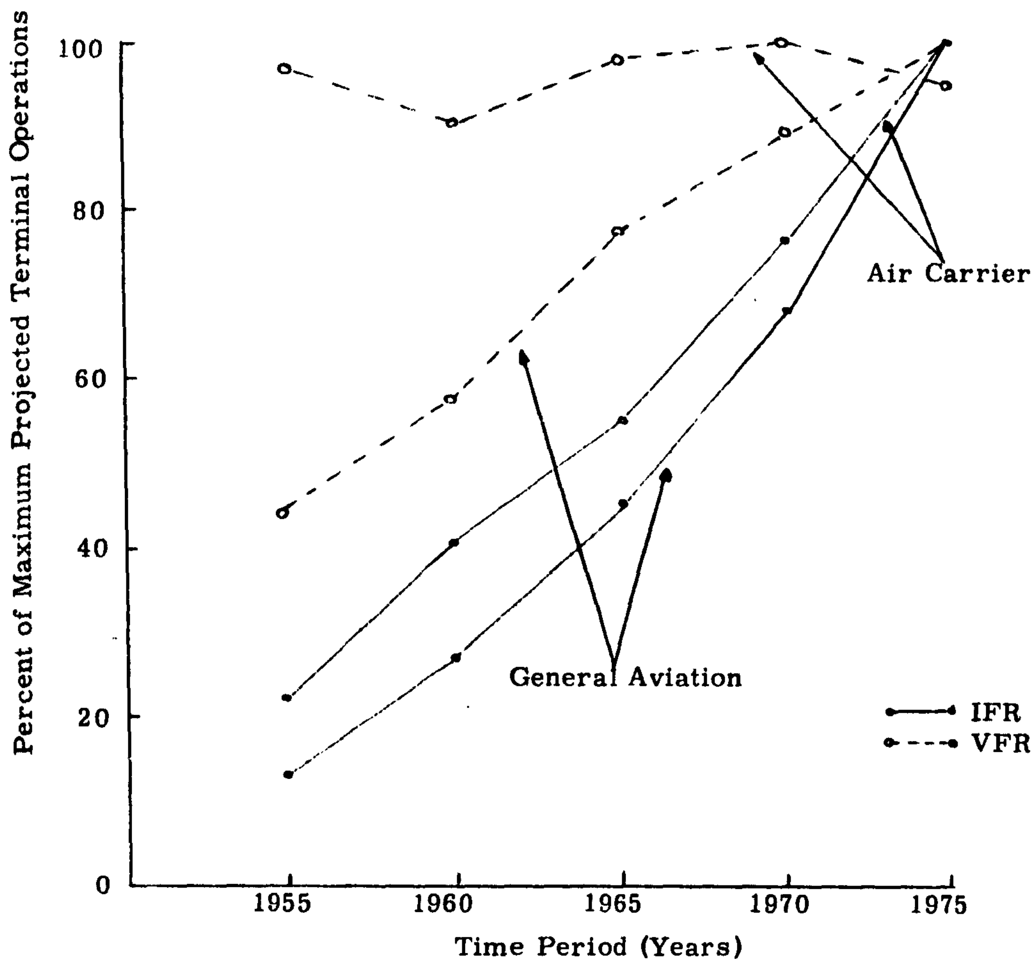
4. <u>Air Carrier and General Aviation Type of Aircraft</u>: Table A-2 presents a breakdown of the flight characteristics and per cent of each type of general aviation aircraft during the period 1956 to 1975. Table A-3 contains similar information for the air carrier aircraft. The information contained in Table A-2 reveals that the heavy single-engine type aircraft will account for over 66% of all general aviation by 1975. The fastest rate of growth in per cent numbers of general aviation aircraft is the light twin-engine aircraft. By 1975 these two type aircraft

FIGURE A-2: A GRAPHIC COMPARISON OF THE RATE OF INCREASE OF TERMINAL OPERATIONS UNDER IFR AND VFR CONDITIONS[1]



1. See "Federal Aviation Agency. Project Beacon. Report of task force on air traffic control, a study of the safe and efficient utilization of airspace. Washington, D. C.: Author, October 1961."

FIGURE A-3: A GRAPHIC COMPARISON OF THE RATE OF INCREASE OF TERMINAL OPERATIONS OF CIVIL AIRCRAFT TYPES UNDER IFR AND VFR CONDITIONS [1]



1. See "Federal Aviation Agency. Project Beacon. Report of task force on air traffic control, a study of the safe and efficient utilization of airspace. Washington, D. C.: Author, October 1961."

TABLE A-2: CHARACTERISTICS OF GENERAL AVIATION AIRCRAFT [1]

Type	Range of Cruising Speeds in Knots			Range of Cruising Altitudes in Feet			Percent of General Aviation Aircraft Fleet		
	1956	1965	1975	1956	1965	1975	1956	1965	1975
1. Light Single	60-100	70-120	80-250	0-10,000	0-10,000	0-20,000	61.8	----	13.8
a. Piston	60-100	70-120	80-150	0-10,000	0-10,000	0-10,000	----	----	----
b. Turboprop	---	---	150-250	----	----	5000-20,000	----	----	----
c. Turbojet	---	---	---	----	----	----	----	----	----
2. Heavy Single	100-150	120-300	150-500	0-10,000	0-20,000	0-30,000	32.6	----	66.7
a. Piston	100-150	120-200	150-250	0-10,000	0-10,000	0-10,000	----	----	----
b. Turboprop	---	---	200-350	----	----	5000-20,000	----	----	----
c. Turbojet	---	200-300	300-500	----	10,000-20,000	10,000-30,000	----	----	----
3. Light Twin	120-180	150-500	150-550	0-10,000	5000-25,000	5000-30,000	5.0	----	18.6
a. Piston	120-180	150-250	150-300	0-10,000	5000-20,000	5000-20,000	----	----	----
b. Turboprop	---	---	200-350	----	----	10,000-20,000	----	----	----
c. Turbojet	---	350-500	350-550	----	15,000-25,000	15,000-30,000	----	----	----
4. Transport	150-300	150-500	150-550	5000-25,000	5000-40,000	5000-40,000	0.6	----	0.9
a. Piston	150-300	150-300	150-300	5000-25,000	5000-25,000	5000-25,000	----	----	----
b. Turboprop	---	250-400	250-400	----	10,000-30,000	10,000-30,000	----	----	----
c. Turbojet	---	350-550	350-550	----	20,000-40,000	20,000-40,000	----	----	----

1. The information contained in Table A-2 was extracted from "Airborne Instruments Laboratory, Aeronautical Research Foundation and Cornell Aeronautical Laboratory. National requirements for aviation facilities 1956-1975. Volume I, Summary. Washington, D. C.: Authors, May 1957."

TABLE A-3: CHARACTERISTICS OF AIR CARRIER AIRCRAFT [1]

Type	Range of Cruising Speeds in Knots			Range of Cruising Altitudes in Feet			Percent of Common Air Carrier Fleet		
	1956	1965	1975	1956	1965	1975	1956	1965	1975
5. Small Transport	150-300	200-350	200-350	5000-20,000	5000-25,000	5000-25,000	55	41	21
a. Piston	150-250	200-300	200-350	5000-10,000	5000-20,000	5000-20,000	54	20	9
b. Turboprop	250-300	250-350	250-350	10,000-20,000	10,000-25,000	10,000-25,000	1	21	12
c. Turbojet	---	---	---	----	----	----	--	--	--
6. Medium Transport	200-300	200-550	200-550	10,000-25,000	10,000-35,000	10,000-40,000	45	44	45
a. Piston	200-300	200-300	200-300	10,000-25,000	10,000-25,000	10,000-25,000	45	9	4
b. Turboprop	---	300-400	300-400	----	15,000-30,000	15,000-30,000	--	24	28
c. Turbojet	---	450-550	450-550	----	20,000-35,000	20,000-40,000	--	11	13
7. Large Transport	---	480-500	500-550	----	20,000-35,000	20,000-40,000	--	15	34
a. Piston	---	*	*	----	----	----	--	--	--
b. Turboprop	---	*	*	----	----	----	--	--	--
c. Turbojet	---	480-500	500-550	----	20,000-35,000	20,000-40,000	--	15	34

* Possible high-density versions of medium transports--characteristics will be the same as for medium transports.

1. The information contained in Table A-3 was extracted from "Airborne Instruments Laboratory, Aeronautical Research Foundation and Cornell Aeronautical Laboratory. National requirements for aviation facilities 1956-1975. Volume I, Summary. Washington, D. C.: Authors, May 1957."

combined will constitute over 85% of all general aviation aircraft. Table A-3 shows that by 1975 large turbojet transport and medium turboprop transport aircraft will account for about 62% of all air carrier aircraft. The large turbojet transport aircraft is predicted to have the greatest rate of growth in terms of per cent for air carrier aircraft. In summary, heavy single-engine and light twin-engine aircraft will predominate the general aviation field while the large turbojet and medium turboprop will provide the major bulk of aircraft in the air carrier field. Supersonic jet transport and V/STOL aircraft (excluding the helicopter) represent fairly unique types of aircraft. Although there may be few operational supersonic transports by 1975, their performance characteristics during terminal operations will be quite similar to present-day large turbojet aircraft (1). The effect of V/STOL aircraft on terminal operations is difficult to estimate since the concept is resulting in a variety of versions that are being currently explored.

D. A Concept of Terminal Operations at Major Airports

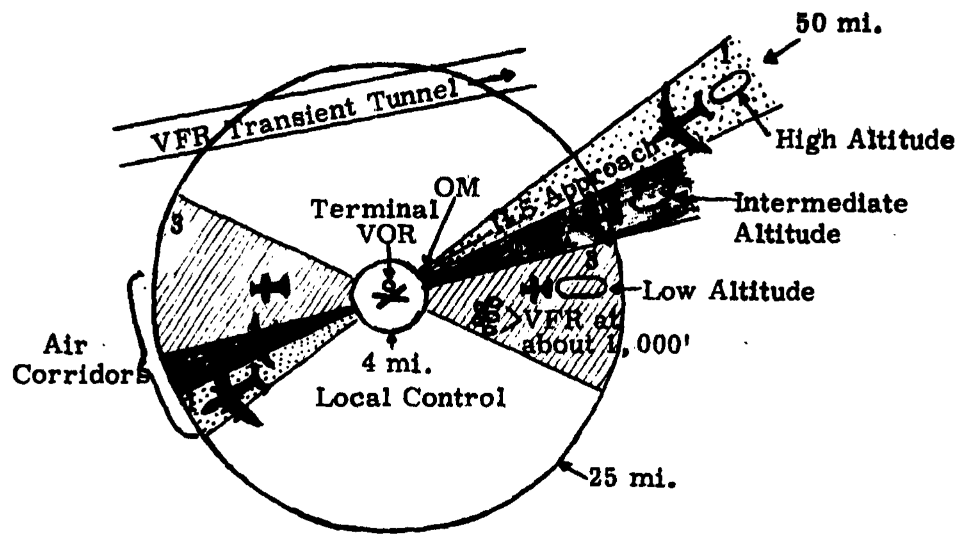
Available background information pertaining to the tasks required of the pilot during terminal operations indicates that a recommended new concept for major airport areas will significantly influence the nature of some of the visual study requirements. The problem and the operational concept proposed to solve this problem are briefly outlined below. A summary of pilot information requirements covering both aircraft and helicopters is presented in Part II of this Appendix.

The most serious operational problem in the major airport areas stems from the mixture of continuously climbing and descending VFR and IFR traffic of widely varying performance capabilities. As a result, a concept (9) has been proposed which physically and operationally separates VFR and IFR traffic and within each of these two categories further separates aircraft of widely differing performance capabilities. The concept is graphically illustrated in Figure A-4. The concept proposes to segregate aircraft according to capability along climb and approach corridors to and from low, intermediate, and upper airways cruise altitudes. The concept envisions an approach control area of 25 miles radius around a controlled airport increasing to 50 miles at high altitude with a local control radius extending to the outer marker, approximately 4 miles. Three approach corridors and three departure corridors would be used and varied according to two or more predetermined plans at the direction of the local controller. These corridors would be "controller concepts" only and would not be shown on any local maps or charts. Controller vectoring and terminal VOR would be used to implement the concept. Variations brought about by wind shifts and weather changes would be accomplished by the controller using appropriate adjustable aids. This concept would eliminate the conventional "downwind, base leg, and final approach" pattern now almost universally used. There would be two conditions under which VFR traffic would not be controlled when entering the 25-mile terminal control zone:

1. When a VFR aircraft desired to land at a noncontrolled airport within the control zone, the aircraft would use a designated one-way tunnel leading to the noncontrolled airport (shown on appropriate charts).

2. A VFR aircraft flying on a route passing through a terminal control zone would use a designated VFR airway with a specified minimum and maximum altitude range (shown on appropriate charts).

FIGURE A-4: A GRAPHIC ILLUSTRATION OF THE RECOMMENDED AIR TRAFFIC CONTROL SYSTEM FOR MAJOR AIRPORTS[1]



1. The information contained in Figure A-4 was extracted from "Federal Aviation Agency. Project Beacon. Report of task force on air traffic control, a study of the safe and efficient utilization of airspace. Washington, D. C.: Author, October 1961."

Part II: Classification of Variables Associated With Terminal Operations and Associated Pilot Information Requirements

CHART A-1: CLASSIFICATION OF AIRPORT/HELIPORT VARIABLES

(The information contained in Charts A-1 - A-4 was obtained from a number of diverse sources including both written materials and individuals)

A. Airport Designation	B. Airport Ground Variables	C. Airport Area/Surround Variables
1. Type a. Airport b. Heliport c. Helipad 2. Nature a. Primary (major) Airport b. Secondary Airport 3. Specificity a. Specific Airport b. Airport Class 4. Status a. Existing Airport b. Proposed Airport 5. Locale a. Metropolitan Area b. City c. Town d. Other (Helipad)	1. Surface Variables a. Runways b. Taxiways c. Bypass Areas d. Ramps e. Runup Pads f. Turnons g. Turnoffs h. Under-run Areas i. Over-run Areas j. Aprons 2. Visual Aid Variables a. Beacons b. Approach Lights/Marks c. Angle of Approach Indicators d. Threshold Lights/Marks e. Heliport Boundary Lights/Marks f. Heliport Entry Point Lights/Marks g. Centerline Lights/Marks h. Runway End Identifiers i. Runway Edge Lights/Marks j. Distance Remaining Lights/Marks k. Turnoff Lights/Signs l. Taxiway Signs/Lights m. Ramp Signs/Lights n. Intersection Signs	1. Airport Area Variables a. Structures (e.g. hangars, towers) b. Terminal Area (e.g. buildings) c. Air/Ground Control Systems (e.g. ILS, GCA) 2. Airport Surround Variables a. Topological (1) Man-made (2) Natural b. Geomorphic (1) Flood Plain (2) Coastal Plain (3) Plateau (4) Piedmont (5) Mountainous

CHART A-2: CLASSIFICATION OF AIRCRAFT VARIABLES

A. Aircraft Function

1. Private Aircraft
2. Commercial Aircraft
3. Military Aircraft

B. Aircraft Type

1. Light Single (2 passengers)
2. Heavy Single (2-5 passengers)
3. Light Twin (5-10 passengers)
4. General Aviation Transport (business)
5. Small Transport (up to 50 passengers)
6. Medium Transport (50-100 passengers)
7. Large Transport (greater than 100 passengers)

C. Aircraft Engine

1. Piston
2. Turboprop
3. Turbojet

D. Special Types

1. Helicopters
2. VTOL and STOL Aircraft
3. Supersonic Transport

CHART A-3: CLASSIFICATION OF AMBIENT VARIABLES

A. Illumination
   1. Day
   2. Night
   3. Sunrise/Twilight

B. Visibility
   1. VFR (Day)
   2. IFR (Day)
   3. VFR (Night)
   4. IFR (Night)

C. Temperature
   1. Seasonal Average
   2. Variability Range
   3. Variability Rate

D. Moisture Content/Composition
   1. Dry
   2. Fog
   3. Rain

E. Foreign Elements
   1. Dust
   2. Smoke
   3. Smog

F. Wind
   1. Velocity
   2. Variability (Gusts)
   3. Prevailing Direction(s)
   4. Distribution by Altitude

G. Cloud Cover
   1. Percent Cloud Cover
   2. Altitude
   3. Height (Thickness)
   4. Type

CHART A-4: CLASSIFICATION OF AIRPORT UTILIZATION VARIABLES

A. Airport Purpose

1. General Aviation (Private)
2. Air Carrier (Commercial)
3. Military
4. Combinations of above

B. Aircraft Utilization

1. Conventional (Piston, Turboprop, Turbojet)
2. Helicopter
3. Both

C. Airport Service

1. Local
2. National
3. International
4. Combinations of above

D. Airport Capacity

1. Air Traffic
2. Ground Traffic
3. Both

E. Airport Community Characteristics

1. Population Number and Distribution
2. Transportation Facilities to and from Airport
3. Economic Structure
4. Major Industries, Business, Commerce and their Distribution
5. Sociological/Cultural Structure
6. Rate of Area Growth and Growth Potential

F. Other Factors Affecting Airport Utilization

1. Air/Ground Traffic Control Facilities
2. Airport Design and Layout
3. Airport Expansion and Growth Potential
4. Other Airports in Area
5. Geographic Relationship to Other Areas

CHART A-5: AIRCRAFT TERMINAL OPERATIONS AND ASSOCIATED INFORMATION REQUIREMENTS[1]

A/C Flight/Ground Phases	Information Requirements
1. Initial Approach	a. Identification of Airport b. Identification of Duty Runway
2. Circling	a. Direction of Flight Path with Respect to Duty Runway b. Distance from Runway Edges c. Distance from Runway Threshold
3. Final Approach	a. Identification of Duty Runway b. Distance to Threshold when Threshold Not Visible c. Changes and Rates of Change in: (1) Distance between A/C Point at Which Glide Path Will Meet the Ground (2) Attitude of Aircraft--Pitch, Roll, Heading--Line of Coordination (3) Glide Path with Respect to Ideal Glide Slope

1. Coleman, H. J. A human factors study of the integrated visual approach and landing aids (IVALA) system. Eglin Air Force Base, Fla.: Air Research and Development Command, Air Proving Ground Center, December 1959. (APGC-TR-59-52)

Lane, J. C., & Cumming, R. W. The role of visual cues in final approach and landing. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, May 1956. (Human Engineering Note 1)

Lybrand, W. A., Vaughan, W. S., Jr., & Robinson, J. P. Airport marking and lighting systems, a summary of operational tests and human factors. Final Report. Arlington, Va.: Human Sciences Research, Inc., May 1959. (HSR-RR-59/1-Mk, Contract No. FAA/BRD-13)

Lybrand, W. A., Vaughan, W. S., Jr., & Robinson, J. P. Airport marking and lighting systems, a summary of operational tests and human factors. Condensed Report. Arlington, Va.: Human Sciences Research, Inc., May 1959. (HSR-RR-59/6-Mk, Contract No. FAA/BRD-13)

Lybrand, W. A., Havron, M. D., Gartner, W. B., Scarr, H. A., & Hackman, R. C. Simulation of extra-cockpit visual cues in contact flight transition trainers. Lackland Air Force Base, Tex.: Air Force Personnel and Training Research Center, February 1958. (TR-58-11, Contract AF 41(657)-69, ASTIA Document No. AD 152 123)

CHART A-5 (Continued)

A/C Flight/Ground Phases	Information Requirements
4. Flare-out and Landing	a. Identification of Safe Landing Area b. Changes and Rates of Change in: (1) Distance between Aircraft and Point at Which Glide Path Will Meet the Ground (2) Attitude of Aircraft--Pitch, Roll, Heading--Line of Flight Coordination (3) Glide Path with Respect to Extended Runway Centerline and to Ideal Glide Slope (angle to ground) (4) Displacement of Ground Roll from an "Ideal" Roll Parallel to Runway Edges c. Runway Length Remaining d. Identification of Duty Runway Exits
5. Turnoff and Taxiing	a. Identification of Duty Runway Exits b. Identification of Safe Taxiing and Parking Areas c. Changes and Rates of Change in: (1) Direction of Ground Roll with Respect to Sides of Taxiway (2) Distance of Aircraft Structures from Limits of Safe Taxiing and Parking Area d. Taxi Route Information Particularly at Intersections
6. Takeoff	a. Distance of Initial Aircraft Position from Runway Edges and Threshold b. Runway Length Remaining c. Changes and Rates of Change in: (1) Direction of Ground Roll with Respect to Runway Edges (2) Attitude of Aircraft after Breaking Ground--Pitch, Roll, Heading --Line of Flight Coordination

CHART A-6: HELICOPTER TERMINAL OPERATIONS AND ASSOCIATED INFORMATION REQUIREMENTS [1]

Helicopter Flight Phases	Information Requirements
1. Initial Approach	a. Identification of Heliport/Helipad b. Identification of Landing Area
2. Circling	a. Direction of Flight Path with Respect to Landing Area Entry Point during Downwind Leg b. Distance from Landing Area Boundaries during Downwind Leg c. Distance from Touchdown Area during Base Leg
3. Final Approach	a. Identification of Touchdown Area b. Changes and Rates of Change in: (1) Distance between Helicopter and Point at Which Glide Path Will Meet Hover Point (2) Attitude of Helicopter--Pitch, Roll, Heading--Line of Flight Coordination (3) Glide Path with Respect to Ideal Forward Speed
4. Hovering and Landing	a. Identification of Safe Landing Area b. Changes and Rates of Change in: (1) Distance between Helicopter and Point at Which Glide Path Will Meet Hovering Altitude (2) Attitude of Helicopter--Pitch, Roll, Heading--Line of Flight Coordination (3) Glide Path with Respect to Hovering Point (4) Displacement of Ground Roll from an "Ideal" Zero Drift in Landing c. Touchdown Point Location d. Identification of Landing Area Exit Point

1. Frey, R. B., & Havron, M. D. An analysis of the helicopter pilot's landing task. Arlington, Va.: Human Sciences Research, Inc., November 1961. (HSR-RR-61/16-Mk-X, Contract No. FAA/BRD-401)

Virnelson, T. R., & Vaughan, W. S., Jr. Heliport lighting design solutions to pilot information requirements. Arlington, Va.: Human Sciences Research, Inc., December 1961. (HSR-RR-61/17-Mk-X, Contract No. FAA/BRD-401)

APPENDIX B

BASES FOR RATING TECHNIQUES

APPENDIX B: BASES FOR RATING TECHNIQUES

I. Physical Fidelity Requirements

A. Photometrics/Colorimetrics Variables

1. Pictorial Element Computation: Rating 0 (P) -- State-of-the-art of elements has not advanced far enough to provide linear light intensities. Extremely difficult to produce different colors due to elements themselves. Some are gas-filled; others have different internal structures.

2. Film: Rating 0 (P) -- Variables affecting exposure of film such as ambient light, type of film, type of lens, type of projector equipment, etc., does not provide photometric advantages. Color can be reproduced but not in true form; film composition and development process determines this.

3. Direct Viewing: Rating 0 (P) -- Lack of control of light intensity from illumination source to any degree of accuracy. Color can be reproduced but cannot be accurately measured because of variations in pigments and dyes and object surfaces.

4. Optical, Diascopic: Rating 0 (P) -- Lack of control of light intensity through transparencies (varies as function of distance from light source to transparency). Colored transparencies are used but dyes that produce the colors are not true to form, therefore, not measurable.

5. Optical, Epidiascopic: Rating 0 (P) -- Lack of control of light intensity around opaque models (varies as a function of distance from light source to models). Color is extremely difficult to produce in this technique.

6. Closed Circuit Television: Rating 0 (P) -- Components used limit amount and degree of light available in this technique. Color is extremely difficult to produce in this technique and quite costly. Colors are not true to form because of phosphors used.

7. Synthetic Image Generation: Rating 0 (P) -- Same as Closed Circuit Television in general; however, color considerations are same as those in the Optical, Diascopic technique as transparencies are used in most of the variations in this technique. The variation in technique which utilizes electronic abstraction and computation is confronted with color considerations same as Closed Circuit Television.

B. Ambient Variables

1. Pictorial Element Computation: Rating 0 (P) -- Fog, scud, cloud, etc., are extremely difficult to produce in this technique. Presentations are accomplished by sequentially illuminating specific display elements on the display panels by means of computed voltages. The components (EL lamps) limit the variance of intensity necessary to produce ambient conditions.

2. Film: Rating 1 (F) -- If each flight condition is measured in real world in general then a reasonable correlation in the simulator could be produced. (This rating unstable, could be 0 or 1.) Actually only an analog could be developed in the simulator versus the real world.

3. Direct Viewing: Rating 0 (P) -- Only a small degree of measurability can be attained in this technique in the simulation of ambients because of the limited number of variables involved. Quantities such as model illumination, attenuation screens, etc., may be varied; however, no validity can be ascertained in the resultant analog.

4. Optical, Diascopic: Rating 0 (P) -- This technique does not afford the simulation of ambients to any usable degree as the range of optimum simulated conditions is restricted to dusk and twilight presentations because of the inherent loss of light intensity.

5. Optical, Epidiascopic: Rating 0 (P) -- Same as Diascopic.

6. Closed Circuit Television: Rating 0 (P) -- Ambients can be simulated in this technique; however, no precise measurability can be made. The validity of the measurement is extremely low.

7. Synthetic Image Generation: Rating 0 (P) -- Same as Closed Circuit Television, except more extreme because of character of input to system, i.e., no model complex, only 2-D photo masks.

C. Spatial Variables

1. Pictorial Element Computation: Rating 1 (F) -- Objects can be accurately presented on the screen in relation to other objects especially in plan view perspective. The measurability of this technique is medium.

2. Film: Rating 2 (G) -- The cameras that record the real world environment precisely registers the objects and their relationships to each other.

3. Direct Viewing: Rating 2 (G) -- Model complex scaling accuracy qualifies this technique.

4. Optical, Diascopic: Rating 0 (P) -- Because of dispersion of light bundles in passing through transparencies and perspective being a function of light source to transparencies, this technique does not afford a good spatial rating.

5. Optical, Epidiascopic: Rating 0 (P) -- Same as Diascopic except opaque models are used instead of transparencies.

6. Closed Circuit Television: Rating 2 (G) -- Good because of model complex accuracy; however, scale factor must be taken into consideration.

7. Synthetic Image Generation: Rating 1 (F) -- Spatial rating in this technique is dependent on accuracy of encoding data on photo masks. A fair degree of accuracy could be accomplished.

D. Dynamic Variables

1. Pictorial Element Computation: Rating 0 (P) -- State-of-the-art has not produced any practical solution to the problem of providing dynamics for this technique.

2. Film: Rating 0 (P) -- Because of programmed nature of this technique, only a limited modification of any flight control can be attained. It is always limited by the aircraft taking the pictures.

3. Direct Viewing: Rating 1 (F) -- Limited only by precision of small hardware and accuracy of servo systems.

4. Optical, Diascopic: Rating 0 (P) -- Transfer of cues as a result of motion in this technique is basis for poor rating. Difficulty is also experienced in servoing too close or too far of point light source to transparencies in beam width of light bundles.

5. Optical, Epidiascopic: Rating 1 (F) -- Transfer of cues is no problem in this technique; however, size of opaque models and cooling of light source are limiting factors.

6. Closed Circuit Television: Rating 1 (F) -- Precision of hardware and accuracy of servo systems are only limiting factors in this technique.

7. Synthetic Image Generation: Rating 1 (F) -- Same as Closed Circuit Television.

II. Perceptual Fidelity Requirements

A. Brightness and Color Contrast

1. Pictorial Element Computation: Rating 1 (F) -- Brightness in this technique (nonprojected mode) primarily depends on the elements used. Most elements (bulbs, EL lamps, etc.) are relatively efficient in light giving properties.

2. Film: Rating 2 (G) -- The projection lamp plus the distance of "flux throw" determines the maximum brightness available in this technique. High wattage lamps are available.

3. Direct Viewing: Rating 2 (G) -- Model illumination presents no major problem in this technique.

4. Optical, Diascopic: Rating 1 (F) -- High intensity point light source is sufficient to produce a relatively useful amount of brightness.

5. Optical, Epidiascopic: Rating 0 (P) -- Models are opaque and therefore decrease amount of light reaching collective lens.

6. Closed Circuit Television: Rating 0 (P) -- Brightness is a major problem in this technique due to TV projection components and CRT's.

7. Synthetic Image Generation: Rating 0 (P) -- Same as Closed Circuit Television.

B. Atmospheric Representation

1. Pictorial Element Computation: Rating 0 (P) -- Extremely difficult to simulate different environments in this technique.

2. Film: Rating 2 (G) -- Films of actual flight conditions can be provided from the real world. Inherent advantages of film provide fidelity of reproduction.

3. Direct Viewing: Rating 1 (F) -- Because of scale factor and small model area of this technique, simulation of environmental conditions are somewhat impeded.

4. Optical, Diascopic: Rating 0 (P) -- Environmental conditions are difficult to simulate in this technique as the range of optimum simulated conditions is restricted to dusk and twilight presentations because of the inherent loss of light intensity.

5. Optical, Epidiascopic: Rating 0 (P) -- Same as Diascopic.

6. Closed Circuit Television: Rating 2 (G) -- No major problems encountered in the simulation of atmospherics in this technique.

7. Synthetic Image Generation: Rating 1 (F) -- Some problems will be apparent in the simulation of atmospherics with this technique because of the glass transparencies that comprise the model input. Either the transparencies must be "fogged" or the system must be defocused and/or scan impeded to simulate certain conditions.

C. Object/Contour Representation

1. Pictorial Element Computation: Rating 1 (F) -- Reasonable fidelity can be accomplished with this technique. Rating is a function of total number of elements available, type of programming, and type of elements utilized.

2. Film: Rating 2 (G) -- Film has capability of good fidelity and film exposed in real world environment reproduces the scene to a great degree.

3. Direct Viewing: Rating 2 (G) -- 3-D models are used in this technique and depending on scale factor and quality of lens, good representation is accomplished.

4. Optical, Diascopic: Rating 0 (P) -- Light passing through a transparency suffers a decrease in brightness. The brightness differential between objects and contours is decreased as a result of this decrease in overall brightness.

5. Optical, Epidiascopic: Rating 1 (F) -- 3-D opaque models are used in this technique and despite the brightness problem, brightness differentials between objects and contours are apparent.

6. Closed Circuit Television: Rating 2 (G) -- Same as Direct Viewing.

7. Synthetic Image Generation: Rating 1 (F) -- Because models consist of a 2-D plan view glass plate, some difficulty is experienced in this technique. Bunching of scan lines provides some alleviation of this problem.

D. Apparent Motion Perspective

1. Pictorial Element Computation: Rating 0 (P) -- Achievement of good motion perspective is a major problem in this technique because of switching time and "crosstalk" in elements. Resolution is not too good in current systems.

2. Film: Rating 2 (G) -- Reproduction of real world scene and the aircraft's motion through it is recorded with reasonable fidelity on the film.

3. Direct Viewing: Rating 1 (F) -- Scale factor and model size determine motion perspective in this technique.

4. Optical, Diascopic: Rating 0 (P) -- A reversal of texturing cues becomes apparent in this technique as the simulated aircraft decreases altitude.

5. Optical, Epidiascopic: Rating 1 (F) -- Scale factor and total brightness determine motion perspective in this technique.

6. Closed Circuit Television: Rating 1 (F) -- The simulated aircraft flies over the 3-D models and although resolution is poor, motion perspective cues are presented.

7. Synthetic Image Generation: Rating 1 (F) -- Limiting factor for this technique is resolution.

III. Simulator Requirements

A. Compatibility

1. Pictorial Element Computation: Rating 0 (P) -- In both modes of this technique (projected - nonprojected), a computer of some form must be used. This increases number of conversion units/equipment.

2. Film: Rating 1 (F) -- Voltages and shaft rotations translating six degrees of freedom must be adapted to special lenses of projector. This requires extra small and precision hardware and servo systems.

3. Direct Viewing: Rating 1 (F) -- Extra small and precision hardware and servo systems are required to move the pickup lens over the scaled objects.

4. Optical, Diascopic: Rating 1 (F) -- Servo systems and hardware necessary to move the light source and/or transparencies limited in terms of space especially in transparency movement.

5. Optical, Epidiascopic: Rating 1 (F) -- Same as diascopic except more difficulty with lens.

6. Closed Circuit Television: Rating 2 (G) -- Large components and standard servo systems provide good compatibility.

7. Synthetic Image Generation: Rating 2 (G) -- Components of this system should provide good compatibility because of precise electronic displacement of electron beams, i. e., voltage summations.

B. Cost Factor

1. Pictorial Element Computation: Rating 0 (P) -- Complex hardware plus lack of empirical data would increase cost in projected mode. Computer cost plus picture elements cost such as electroluminescent lamps would increase cost of solid state nonprojected.

2. Film: Rating 1 (F) -- Modified projector costs plus film costs would be somewhat large; however, data on systems are available and development time and cost would be small.

3. Direct Viewing: Rating 1 (F) -- Hardware costs would not be absorbent in this case, but model cost and development time/costs would be high.

4. Optical, Diascopic: Rating 2 (G) -- Relatively low hardware costs plus large amount of data available on this technique. Development time/costs would be small.

5. Optical, Epidiascopic: Rating 2 (G) -- Same as Diascopic.

6. Closed Circuit Television: Rating 2 (G) -- Same as Diascopic.

7. Synthetic Image Generation: Rating 0 (P) -- No systems utilizing this technique have been in production status. Hardware costs plus development time/costs would be heavy.

C. Durability

1. Pictorial Element Computation: Rating 1 (F) -- No adverse conditions would exist in this technique except in nonprojected solid state devices. The EL lamps would present some problems on life expectancy.

2. Film: Rating 2 (G) -- Projectors have reasonably long life. Film has extremely long life expectancy.

3. Direct Viewing: Rating 2 (G) -- Lenses and models have long life expectancy.

4. Optical, Diascopic: Rating 2 (G) -- No adverse conditions except a small number in the transparencies.

5. Optical, Epidiascopic: Rating 1 (F) -- Intense heat generated in light source could cause some discrepancies in models in this technique.

6. Closed Circuit Television: Rating 2 (G) -- Long life expectancy.

7. Synthetic Image Generation: Rating 2 (G) -- Long life expectancy anticipated.

D. Flexibility

1. Pictorial Element Computation: Rating 0 (P) -- Complex programming necessary in both modes plus switching matrix changes necessary in solid state nonprojected.

2. Film: Rating 1 (F) -- Even though film can be exposed in many different problem areas, the time/cost of real world flying would be somewhat high.

3. Direct Viewing: Rating 0 (P) -- Model complex would require a change, and the time/cost factor would be high.

4. Optical, Diascopic: Rating 0 (P) -- Same as Direct Viewing.

5. Optical, Epidiascopic: Rating 0 (P) -- Same as Direct Viewing.

6. Closed Circuit Television: Rating 0 (P) -- Same as Direct Viewing.

7. Synthetic Image Generation: Rating 2 (G) -- Different AML configurations relatively easy to produce (inexperienced personnel).

E. Growth Potential

1. Pictorial Element Computation: Rating 2 (G) -- GP excellent in this technique especially in solid state nonprojected mode. Almost unlimited in this mode.

2. Film: Rating 0 (P) -- Difficult to add projectors because of lens synchronization and high cost of real world flying for new film exposures.

3. Direct Viewing: Rating 2 (G) -- Change of model complex affords excellent GP.

4. Optical, Diascopic: Rating 0 (P) -- Change in models more difficult in this mode of technique. Physical size limits ease of change. Screen is also limited to small Δ of change in physical dimensions because of special shape.

5. Optical, Epidiascopic: Rating 0 (P) -- Same as Diascopic.

6. Closed Circuit Television: Rating 1 (F) -- Change of model complex somewhat limited and expensive.

7. Synthetic Image Generation: Rating 2 (G) -- More glass plates could be added increasing/decreasing scaled area. Electronic concept more easily modified.

F. Maintainability

1. Pictorial Element Computation: Rating 1 (F) -- Switching matrix in nonprojected mode would present some problems due to high density packaging.

2. Film: Rating 2 (G) -- Small number of special maintenance problems involved.

3. Direct Viewing: Rating 2 (G) -- Same as Film.

4. Optical, Diascopic: Rating 2 (G) -- Same as Film.

5. Optical, Epidiascopic: Rating 1 (F) -- Heat is a problem in this technique and would present some difficulties in maintenance.

6. Closed Circuit Television: Rating 2 (G) -- Same as Film.

7. Synthetic Image Generation: Rating 1 (F) -- Some difficulty is anticipated due to high density packaging and new components.

G. Measurability

1. Pictorial Element Computation: Rating 1 (F) -- Voltage differential measurements relatively easy to accomplish in nonprojected. Projected mode presents some problems in measurement.

2. Film: Rating 0 (P) -- Programmed nature of this technique makes measurement difficult. Also no accurate film spent rate indicators available.

3. Direct Viewing: Rating 1 (F) -- Highly controlled environment provides reasonably good measurability; however, scale factor and small voltage increments impede measurements somewhat.

4. Optical, Diascopic: Rating 0 (P) -- Provisions for precise measurements have not been engineered in existing systems utilizing this technique. In some cases various types of electrical converters would be necessary for precise measurements.

5. Optical, Epidiascopic: Rating 0 (P) -- Same as Diascopic.

6. Closed Circuit Television: Rating 0 (P) -- Same as Diascopic.

7. Synthetic Image Generation: Rating 1 (F) -- Voltage differentials could be obtained reasonably well and with reliability.

H. Packageability

1. Pictorial Element Computation: Rating 2 (G) -- High density packaging of components.

2. Film: Rating 2 (G) -- Small size of projector and film.

3. Direct Viewing: Rating 1 (F) -- Relatively small size of lens and models; however, scale factor plays important role in size of models.

4. Optical, Diascopic: Rating 1 (F) -- Models are relatively large, but other components are small.

5. Optical, Epidiascopic: Rating 1 (F) -- Same as Diascopic.

6. Closed Circuit Television: Rating 0 (P) -- Hardware is large in size and number especially model complex.

7. Synthetic Image Generation: Rating 2 (G) -- Hardware has high density packaging and small number of units comprise the system.

I. Procurability

1. Pictorial Element Computation: Rating 0 (P) -- Extremely small number of systems have been developed. Would require long procurement time.

2. Film: Rating 1 (F) -- Some systems have been developed. Procurement time would be relatively small.

3. Direct Viewing: Rating 1 (F) -- Same as Film.

4. Optical, Diascopic: Rating 2 (G) -- A number of systems utilizing this technique are available.

5. Optical, Epidiascopic: Rating 2 (G) -- Same as Diascopic.

6. Closed Circuit Television: Rating 2 (G) -- Same as Diascopic.

7. Synthetic Image Generation: Rating 0 (P) -- Extremely small number of systems are undergoing development. Would require long procurement time.

J. Reliability

1. Pictorial Element Computation: Rating 2 (G) -- No serious problem in reliability in this technique. Only limiting factor is components.

2. Film: Rating 2 (G) -- Same as Pictorial Element Computation.

3. Direct Viewing: Rating 2 (G) -- Same as Pictorial Element Computation.

4. Optical, Diascopic: Rating 2 (G) -- Same as Pictorial Element Computation.

5. Optical, Epidiascopic: Rating 2 (G) -- Same as Pictorial Element Computation.

6. Closed Circuit Television: Rating 2 (G) -- Same as Pictorial Element Computation.

7. Synthetic Image Generation: Rating 2 (G) -- Same as Pictorial Element Computation.

APPENDIX C

SIX EXAMPLES OF VISUAL SIMULATION STUDIES CLASSIFIED IN TERMS OF STUDY SETTING

APPENDIX C: SIX EXAMPLES OF VISUAL SIMULATION STUDIES CLASSIFIED IN TERMS OF STUDY SETTING

Reference/Source	Study Setting Index	Description of Study/Setting	Comments
Mote, F. A., [illegible] The effect of brief flashes of light upon peripheral dark adaptation. J. exp. Psychol., 1961, 64, 233-244.	I Laboratory A. Incident Light	Subjects were exposed to a white light varying in intensity from 395 to 3160 millilamberts and durations from 0.01 to 2.00 seconds. Both pre-exposure and test stimuli were imaged 10^{o} from the fovea on the nasal portion of the right retina.	As light intensity, duration of exposure, or both increased, time required to reach the final dark adapted threshold increased. Time period needed for complete dark adaptation varied from about 5 to 15 minutes. The findings have general implications to flight situations requiring transiting from more intense illumination to considerably less illumination, e.g., approach to runway lights.
Vipond, L. C., Supervisor Engineer, Airport Branch, Development Division, FAA. Personal Communication	II. Static and Dynamic ("open loop") Simulation B. Models (Scaled)	Construction of a fog chamber 800 feet long and 30 feet wide is being completed at University of California using a 10:1 scale throughout. Experiments will begin in October 1962. The fog chamber is designed to investigate photometric and colorimetric problems under simulated fog conditions with varying amounts of surround illumination.	Although there are limited compensatory or "closed loop" features in the design of the fog chamber, it may be more accurately characterized as an "open loop" dynamic simulator. Some freedom exists in speed and lateral movement of the 4-place Cessna cabin. The Cessna cabin is suspended and moves along an overhead track simulating the last 1000 feet of a final approach, in addition to the flare-out and touchdown. Films taken during the approaches provide a supplementary data collection device.

APPENDIX C (continued)

Reference/Source	Study Setting Index	Description of Study/Setting	Comments
Weissman, N. W., et.al. Sensitivity to angular change as a function of retinal angle. Arlington, Va.: Human Sciences Research, Inc., May 1962. (HSR-RR-61/13-Mk-X, Contract No. FAA/BRD-401).	III. Static and Dynamic ("closed loop") Simulation A. Analog (abstract) Simulation	Two psychophysical experiments using a method of simultaneous and successive adjustment were conducted to determine if any of six basic geometric designs (e.g., circle) yielded differential information regarding angular change. No consistent differences were found; and, as a consequence, a third experiment was conducted using two longitudinally separated illuminated points as the only visual references. These two points simulated the top and bottom borders of a heliport lighting display.	The results of the third experiment suggested that retinal angles of nine to ten minutes yield most accurate judgments of angular change, and retinal angle of six minutes and less yield least accuracy. A retinal angle of three minutes separation appeared to fuse to a single point. The study and findings have implications for developing design criteria for providing information regarding vertical displacement from a desired helicopter glide slope during final approach.
McKelvey, R.K., et.al. Simulation comparison of 3 runway landing zone lighting patterns. Atlantic City: Federal Aviation Agency, Bureau of Research and Development, April 1961. (Task 411-3-4R)	III. Static and Dynamic ("closed loop") Simulation B. Real World Simulation	Three runway landing zone lighting patterns were compared using a "closed loop" dynamic visual simulator. Each of twelve pilot subjects made eight approaches on the three patterns. During most of the approaches, the experimenter affected a displacement on each axis of flight. The pilots were required to make corrective maneuvers if and when they perceived a displacement. A performance checklist and questionnaire were used.	The data from the flight performance checklist showed statistically significant differences, and there existed a trend in preference for one of the patterns. The study and study setting have implications for an approach to display design as well as use of real world dynamic simulators for screening designs prior to field testing.

APPENDIX C (continued)

Reference/Source	Study Setting Index	Description of Study/Setting	Comments
Human Sciences Research, Inc. Design criteria for visual aids for V/STOL aircraft. Contract No. FAA/BRD-401.	IV. Field (Static and Dynamic) A. Field Experiment	A planned field experiment will be conducted to determine the general functional relationship between separation of two point source light units and the amount of guidance provided helicopter pilots for controlling angle of approach, rate of closure, heading, and roll. Five test pilots will execute 8 approaches under three different conditions of light separation. Performance measures found to reflect changes in information, as determined during pretest, will be utilized.	The results of this field experiment should serve as an initial basis for ultimately specifying empirically and quantitatively derived design criteria for guiding the functional construction of heliport lighting displays.
Cumming, R. W. Interim report on the operational evaluation of two visual glidepath systems. Melbourne: Department of Supply, Australian Defence Scientific Service, Aeronautical Research Laboratories, June 1962. (Human Engineering Technical Memorandum 5).	V. Airport/Terminal Area B. Operational Study	Records of heights and speeds at threshold of large jet aircraft (Boeing 707 and DC 8) landing in daylight at Sydney International Airport were studied in order to assess the effectiveness of two visual approach aids under operational conditions. Tracking and fixed cameras were used to record the flight. Pilots were informed on the use of the visual aids by briefing cards. They were not told that the flight paths were being recorded. About 800 observations were made.	The results of the evaluation showed that one of the two visual approach aids led to a significant improvement in control of height. Regarding control of speed, neither aid made any difference. This somewhat unique operational evaluation procedure contains elements of a testing environment performed under normal operational conditions.